The University of Adelaide

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REPORT

OF THE

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

1939-1940

ADELAIDE
AT THE HASSELL PRESS
1941

REPORT OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE

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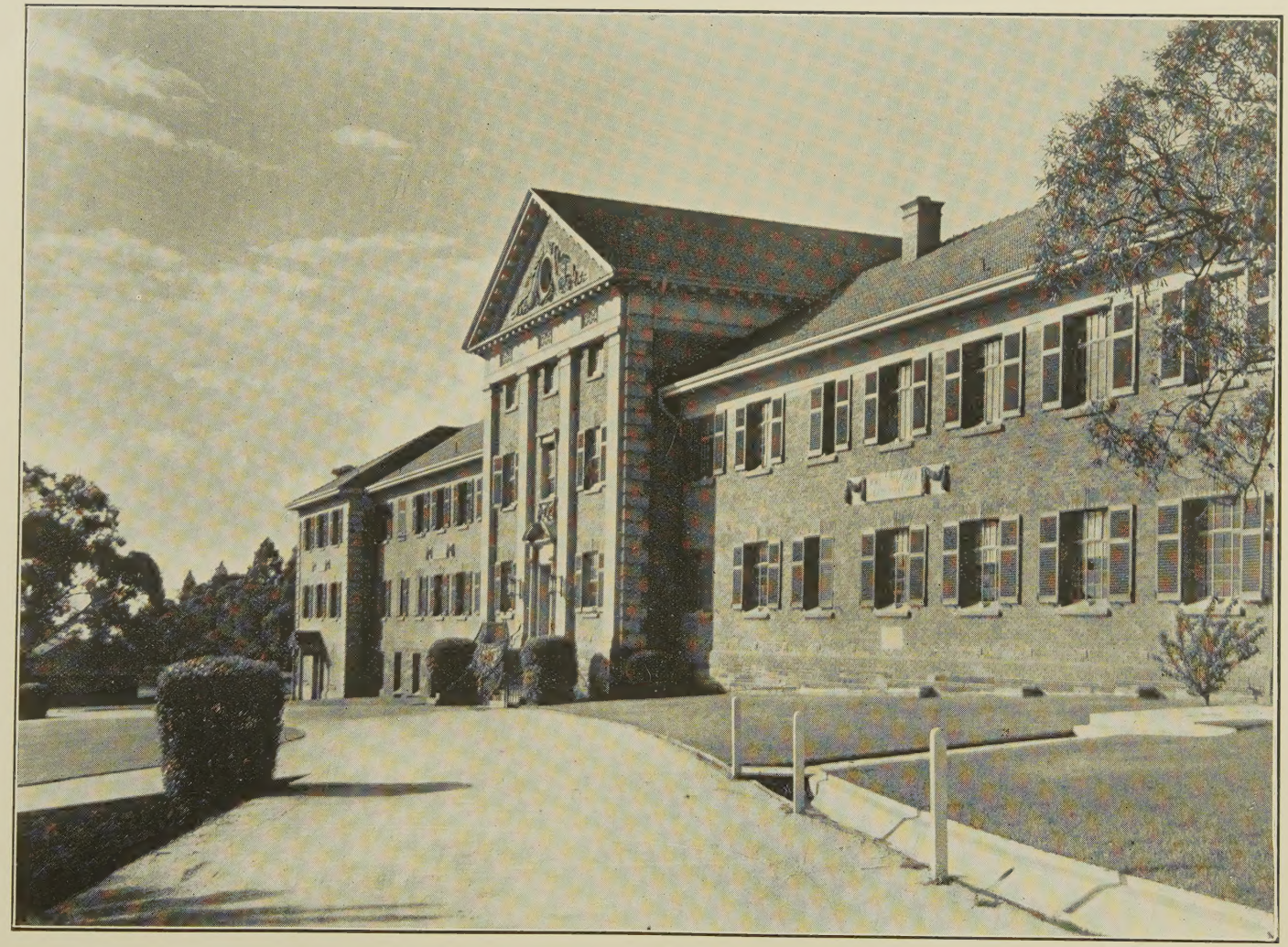

THE LABORATORIES OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE.

The University of Adelaide

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G. H. F. CLARKE, F. H. HOOPER, JEAN MCNEIL.

MEMBERS OF THE LABORATORY AND FARM STAFF IN THE AUSTRALIAN IMPERIAL FORCES:

*J. G. BALDWIN, *F. W. COOK, *R. W. LANGSFORD, B. C. CORNISH, A. J. PIKE.

* Officers of the Commonwealth Council for Scientific and Industrial Research.
† Seconded to Queensland Department of Agriculture.
‡ Absent on study leave.

The Waite Agricultural Research Institute

1. Introduction.

The Waite Agricultural Research Institute was established in 1924 as a result of the gift of the late Mr. Peter Waite to the University of Adelaide for the purpose of furthering the cause of education and research in agriculture and allied subjects. The original endowment comprises an estate of 299 acres of agricultural and grazing land situated near Glen Osmond, a mansion house, and a Trust Fund of £58,450.

The estate lies on the scarp of the Adelaide foothills, within four miles of the city of Adelaide. Portion of the estate comprises wheat land, 280-390 feet above sea-level, whilst the remainder is representative of the hilly country at the foothills of the Mount Lofty Ranges. To the original estate have been added 82 acres by purchase, and a further area of 115 acres associated with the Urrbrae Agricultural High School is leased from the Education Department of South Australia.

The Council of the University decided that the best means of giving effect to the wishes of the donor would be the establishment of an Agricultural Research Institute, in order to enlarge the stock of knowledge relating to agriculture in the widest sense, for the benefit of those engaged in production, as farmers or pastoralists. It appointed its Finance Committee to act as the Board of Management of the Institute.

The active work of the Institute began in March, 1925. and laboratories were improvised in the existing buildings on the estate, pending the erection of permanent structures. The permanent laboratories have been made possible through the generosity of the late Sir John Melrose and the families of the late Mr. John Darling and Mr. Frederick Ranson Mortlock. The John Melrose Laboratory was opened in 1929, the John Darling Laboratory in 1930, and the Ranson Mortlock Laboratory in 1938.

The design of the buildings is such as to permit of additional laboratories as circumstances demand.

In addition to the laboratories, a range of glasshouses, two implement sheds, and a cereal barn have been erected since 1925. The glasshouses include two designed for general work in agronomy, plant pathology, and physiology, one designed for entomology, and a completely enclosed house with numerous compartments suitable for investigations demanding freedom from outside contamination, whether in the form of dust, insect pests, or bacterial infection.

This latter glasshouse has been constructed and is maintained by the Council for Scientific and Industrial Research, primarily for investigations in plant viruses and soil bacteriology.

In 1927 the Empire Marketing Board, the Council for Scientific and Industrial Research, and the University of Adelaide jointly agreed to provide funds for the investigation of the mineral content of pastures in Australia. The Empire Marketing Board agreed to contribute a sum of £1,875 per annum for a period of five years for this co-operative investigation. The Council for Scientific and Industrial Research has contributed annually a sum of £937 towards the maintenance costs of the investigation. When the Empire Marketing Board was discontinued the Trustees of the Carnegie Institution of New York provided funds over a two-year period for the maintenance of these pasture investigations, provided that the University undertook to continue the investigations subsequent to the expiry of the grant. The investigations have been continued jointly by the University and by the Council for Scientific and Industrial Research.

Since 1927 the Division of Animal Health and Nutrition of the Council for Scientific and Industrial Research has maintained at the Waite Institute a field station equipped with feeding pens and a laboratory. Here certain problems in the nutrition of sheep, requiring relatively large numbers of animals, are investigated. Small breeding flocks of Merino and Corriedale ewes are also maintained at the Institute by the Division.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils of the Council for Scientific and Industrial Research.

Under the will of Mrs. Elizabeth Macmeikan, widow, and daughter of the late Mr. Peter Waite, who died on April 5, 1931, her residuary estate, after payment of certain bequests, was left in trust to the University of Adelaide. The net income in the residuary estate is to be paid to the University in perpetuity for establishing and maintaining the study of agriculture, botany, zoology, veterinary science, entomology, horticulture, and forestry by the University, either in connection with the Waite Agricultural Research Institute or otherwise.

In August, 1936, the family of the late Mr. Frederick Ranson Mortlock offered the Council of the University a gift, to be known as the "Ranson Mortlock Trust" for research work in connection with soil erosion and regeneration of pastures on pastoral lands. The gift was accepted by the University, and investigations on pasture regeneration under the terms of the Trust have been initiated.

During 1940 Mr. J T. Mortlock contributed a sum of £1,000 towards the cost of establishing an experimental grazing area on Yudnapinna Station.

Since 1937 Mr James Waite, son of the late Mr. Peter Waite, has made an annual contribution of £100 for research work in connection with the problem of soil erosion.

Apart from its original and subsequent endowments the Waite Research Institute derives its income from appropriations under Acts of Parliament of South Australia, from Commonwealth sources through the Council for Scientific and Industrial Research, and for specific investigations from such organizations as Imperial Chemical Industries Limited, the Australian Wool Board, and the Australian Wine Board.

From the beginning of 1925 until early in 1938 the Waite Institute was under the direction of Dr. A. E. V. Richardson. To Dr. Richardson and to the late Sir Walter Young (who was Chairman of the Finance Committee from 1927 to 1935) the Waite Institute is deeply indebted for the solid progress made during the early years of its establishment.

During recent years experimental work has been conducted at country centres with the goodwill, co-operation, and personal assistance of a number of individuals and organizations. It is a pleasure to record such assistance from the following: Mr. P. J. Baily for Messrs. H. W. Morphett & Co. at Wood's Point, Mr. N. Brookman at Meadows, Mr. R. L. Davidson at Pallamana, Mr. E. E. Scarfe and Mr. D. R. Douglas of the Yudnapinna Pastoral Company, Mr. J. L. Cowan at Glen Lossie, Dr. M. Schneider at Blanchetown and Wood's Well, Mr F. Giles at Salisbury, Mr. F. Coleman, of Saddleworth, Mr. H. Sanders at Yurgo, Mr. J. W. E. Schultz at Jervois, Mr. R. W. Pearson at Brooker, Mr. R. H. Martin at Stonyfell, Mr. R. Goldsack, of Clarendon, Mr. R. Dawson at Robe, Dr. A. G. Price at Tea Tree Gully, Mr. K. Dowding, of Mypolonga, Mr. A. J. McBride at "Karringallana", Kangaroo Island, and Mr. H. L. Rymill at "Karinga", Kangaroo Island, Mr. F. Domaschenz, of Robe, Mr. John Hawker, of "Anama", Clare, and the Adelaide City Council. During the period under review Messrs. H. V. McKay, Massey Harris Pty., Ltd., presented some farm equipment.

2. Scientific Work of the Institute.

The main objective of the Institute is to enlarge the stock of knowledge relating to agriculture in the widest sense, and to pass it on to those actively engaged in agricultural and pastoral pursuits. Expressed in more precise terms, the aim is to conduct researches on plant and soil problems relating to agriculture, and on the insect and fungus pests which affect production.

Under the terms of the University of Adelaide Act 1935, and a subsequent Amendment Act of 1937, the Waite Institute, in addition to conducting researches into specified branches of agricultural science, is to provide advisory services in botany, plant pathology, and entomology to the Minister of Agriculture. By agreement these services were subsequently extended to the Minister of Afforestation.

The University of Adelaide maintains a School of Agricultural Science and courses of instruction for the degree of B.Ag.Sc. Courses of instruction in agriculture, agricultural chemistry, mycology, plant pathology, and entomology for this degree are provided at the Waite Institute.

Although extension work in agriculture is not a function of the Institute, educational work is effected through visits of Agricultural Bureaux, parties of farmers, and other visitors to the experimental fields and laboratories. During the period under review, the Waite Institute has co-operated with the Australian Broadcasting Commission in providing a weekly talk from Stations 5CL and 5CK during the Countryman's Session.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry and of the problems which may be associated with this aspect of agriculture. Animal husbandry is not a feature of the research work of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy, Agrostology, and Plant Genetics.

The investigation of the factors affecting the production of farm crops; the improvement, establishment and management of pastures; the improvement of cereals and fodder plants by hybridization and selection; the identification and control of weeds.

Plant Physiology.

The investigations of the metabolism and growth of plants of agricultural importance.

Plant Pathology.

Investigations of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

Investigations of the insect pests of agricultural and horticultural crops and of forest trees.

Agricultural Chemistry and Soil Investigations.

The survey and classification of Australian soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures.

Bacteriology.

The study of the nodule-forming organism of leguminous plants, with special reference to the use of strains and methods of inoculation suited to Australian crops and farming practice; investigations of problems of importance to the Australian Wine Industry.

The Work of the Institute

Agronomy, Agrostology, and Plant Genetics

The climatic environment of South Australia bears a general resemblance to that of North Africa. It also possesses features in common with those of southern Spain, the Near East, the Cape Province of South Africa, California and Chile. South Australia itself covers 380,000 square miles, and the conditions vary widely, from the extensive deserts and bordering pastoral country of the north to the more limited areas of moderate to good rainfall in the south and south-east.

The primary industries of South Australia have, in the past, been based mainly on the production of wool and wheat. Livestock numbers expanded as a result of the exploitation of native pastures from 1851 to 1890, but subsequently fell, and did not regain their previous maximum until 1932. The wheat industry developed rapidly, largely on the primitive wheat, bare-fallow system, between 1915 and 1932, and has tended to become stabilized, with a reduced acreage, since the depression of 1931–33. These features are not confined to South Australia, but have characterized the agricultural areas of southern Australia generally.

The activities of the Waite Institute from 1925 to 1940 have coincided with a period of reconstruction and change in the pastoral industries, involving in particular the development of new pastures in areas of relatively liberal rainfall, and to a major degree on soils of naturally low fertility. Many problems associated with the improvement of pastures and of soil fertility have thus arisen. The outlook in cereal culture has also changed from one of straight-out wheat production, leading to losses of soil and reduced fertility, to one based on diversified farming. Rotational cropping and the use of temporary pastures, together with a growing interest in new crops, such as flax and linseed, have latterly therefore become increasingly evident. Associated with this trend has been a need for new crop and herbage plants, especially varieties or strains of improved quality, resistant to drought and disease, and adapted to the environmental conditions of southern Australia. The production of these is only possible, for the most part, by the use of modern plant breeding methods.

Researches have been conducted with the object of understanding more fully the factors and principles affecting agricultural and pastoral practices in southern Australia.

1. FIELD CROPS.

The early experiments included rotation trials, fertilizer trials, cultural tests, time and rate of seeding trials, uniformity trials, variety tests and water requirement investigations, with wheat as the main crop. Fertilizer and water requirement tests were also conducted with oats, barley, peas and linseed. The main results of the work have been described in previous reports.

Permanent rotation plots were laid down in 1925, at a time when replicated experiments had not begun to be employed in Australia; these have been continued as a project of long term duration. Fertilizer trials on single crops have been terminated and fertilizer effects are now investigated in association with different systems of crop rotation.

Attention has been devoted in recent years to the effects of forage and pasture

plants on subsequent crop production, and work has been carried out on flax and linseed.

1. Permanent Rotation Experiment.

Eleven systems of crop rotation were commenced in 1925 to ascertain the effects of each upon the yield of wheat. Each course of the eleven systems is represented in every year so that the effects of each season upon all crops sown can ultimately be determined.

The individual seasonal yields and the average yield (1926–40) of each crop in the eleven different rotations are presented in Table 1, on page 70. It will be seen that the four-course rotation has produced higher yields of wheat, oats, and pasture than systems of shorter duration, indicating a more effective maintenance of soil fertility where the four-course rotation has been practised.

The average yields of wheat, with associated crops, for fifteen seasons, in a selected series of these rotations have been as follow:

	Wheat (bush.).	Peas (bush.).	Oats (bush.).	Winter pasture (cwt. air dry).	Sudan grass (cwt. green).
1. Wheat continuously	15·56	—	—	—	—
2. Wheat, peas	27·06	18·54	—	—	—
3. Wheat, bare-fallow	34·61	—	—	—	—
4. Wheat, Sudan grass	34·15	—	—	—	24·60
5. Wheat, oats, fallow	37·02	—	47·47	—	—
6. Wheat, oats, pasture, fallow	44·79	—	57·15	29·11	—

Rotations involving continuous cropping, such as wheat continuously; wheat, peas; wheat, barley, peas, have become heavily infested with weeds.

The results of this experiment should be of increasing significance with the progress of time. In the meanwhile a lead has been given in the design of investigations concerning the use of different four-course systems, including peas, various cereals, forage crops and temporary pastures, combined, in one experiment, with different fertilizer treatments. These have been in progress since 1937 and are discussed in other sections of this report.

2. Fertilizer Experiments.

A full account of the work conducted at the Waite Institute on the responses by field crops to artificial fertilizers has been published in the three previous reports. These investigations, including the extensive experiments dealing with the effects of nitrogenous fertilizers on stubble-sown cereals, have now been concluded, and the responses by wheat, oats, barley, and peas to superphosphate, sulphate of ammonia and lime have been determined, since 1936, in the combined rotational and fertilizer experiment described in section 4.

Tests carried out in 1940 with different forms of superphosphate indicated a possibility that hard, granulated phosphate might give slightly higher yields of wheat grain and straw than ordinary superphosphate. The increases recorded were not significant but were such as to justify further trial.

3. The Effect of Previous Cropping History and Manurial Treatment on the Yield of Wheat.

Interesting results were obtained in an experiment, the primary object of which was to examine the effect of cropping history and manurial treatment on the incidence of "whiteheads". So far as this objective was concerned the result

was unsatisfactory because practically no "whiteheads" occurred in 1939 even on plots which had grown six wheat crops in succession. The land was uncropped prior to 1934, since when it was cropped continuously with wheat until 1937. In that year half the total area was fallowed in one block and wheat cropping continued on the other half. In 1938 the whole area was divided into three parts running across the two blocks of the previous year. These areas were cropped to wheat and to oats and were fallowed respectively. Superphosphate at the rate of 1½ cwt. per acre was applied with the wheat and oats. In 1939 the whole area was laid down in plots of wheat which ran across those of the previous year. There were 54 of these plots receiving differential manurial treatments, using superphosphate at three levels—nil, 1 cwt. and 2 cwt. per acre—and sulphate of ammonia at the same rates, together with all possible combinations of the two. Since each of these 54 plots ran across land which in the previous year was fallowed or grew oats or wheat respectively, each plot at harvest was divided into three sections, each of 1/150th acre, corresponding with 1938 treatments. The area which had been fallowed in 1937 was occupied by the first 27 plots in 1939, while the second series of 27 plots was established on the area devoted to wheat in 1937.

The design of the experiment in 1939 thus enabled the evaluation of effects of manurial treatments in the current year, the residual effects of 1938 cropping or fallow, and the residual effects of 1937 fallow or wheat cropping together with the interactions of manurial treatments and previous cropping history. The data have been analysed for variance by Fisher's method. The results quoted below, with the one exception indicated, satisfy the "Z" test at the one per cent. level.

(A) *The Residual Effects of 1937 Treatments and of 1938 Treatments and their Interaction on the Yield of Wheat in 1939.*

Yield in bushels per ac. ± 1·26.

	1938 treatments.				
	Fallow.	Oats.	Wheat.	Mean. ± 0·73	Difference. ± 1·03
1937 Fallow	45·70	51·23	35·23	**44·50**	*+ 5·84*
1937 Wheat	49·66	37·56	27·76	**38·34**	
Mean ± 0·89	**47·69**	**44·39**	**31·50**		
Diff. from fallow ± 1·26		*— 3·30*	*— 16·19*		

Standard error for differences in interaction table ± 1·78.

(1) The effect of fallow in 1937 irrespective of treatment in 1938 has had a significant effect on yield in 1939. Large blocks are concerned here but the differences are probably real effects due to fallow. In the two years prior to 1937 both areas were in wheat and were fairly uniform in respect to fertility. Thus in 1935 the difference between the blocks was 2·88 ± 0·852 bush. per acre in favour of the block fallowed in 1937, while in 1936 the difference was 0·75 ± 0·39 in favour of the other block.

(2) The yield on plots fallowed in 1938 is significantly better than that of those cropped with oats or wheat. The yield after oats is significantly better than after wheat.

(3) (a) The wheat, fallow, wheat rotation has given a significantly better yield in 1939 than wheat, fallow, fallow. This may be due to a residual effect of phosphate applied to the 1937 wheat plots which the fallow did not receive.

(b) Fallow, oats, wheat is significantly better than all the other rotations tested, with the exception of wheat, fallow, wheat.

(c) Fallow, wheat, wheat is significantly better than wheat continuously, but significantly poorer than fallow, oats, wheat.

(B) *The Effects of Superphosphate Applications on the Yield of Wheat in 1939 and their Interaction with the Effects of 1938 Cropping.*

Yield in bushels per ac. ± 1·57.

Superphosphate.	1938 treatments. Fallow.	Oats.	Wheat.	Mean. ± 0·89	Increase. ± 1·26
P_0	36·30	44·13	28·33	**36·27**	
P_1	50·26	42·84	30·67	**41·28**	*+ 5·01*
P_2	56·49	46·20	35·46	**46·04**	*+ 4·76*
Mean ± 0·89	**47·69**	**44·39**	**31·50**		

S.E. for interaction differences ± 2·22.

(1) Superphosphate at 1 cwt. per acre has increased yield; the additional increase with 2 cwt. per acre is also significant.

(2) The response to superphosphate is most marked on fallowed land—wheat after oats has not responded to superphosphate significantly. Wheat after oats with no addition of phosphate is better than wheat on fallow with no phosphate. This is possibly due to a residual effect of phosphate applied to the oats and not to the fallow. Wheat on wheat stubble has not responded significantly to 1 cwt. but has done so to 2 cwt. of superphosphate per acre.

(C) *The Effects of Applications of Sulphate of Ammonia on the Yield of Wheat in 1939 and their Interaction with the Effects of 1938 Cropping.*

Yield in bushels per ac. ± 1·57.

Sulphate of Ammonia.	1938 treatments. Fallow.	Oats.	Wheat.	Mean. ± 0·89	Increase. ± 1·26
N_0	46·83	39·65	25·43	**37·30**	
N_1	48·35	45·94	32·40	**42·25**	*+ 5·05*
N_2	47·90	47·62	36·67	**44·05**	*+ 1·80*
Mean ± 0·89	**47·69**	**44·39**	**31·50**		

S.E. for interaction differences ± 2·22. Significant at 5% level only.

(1) The increase in yield with the application of 1 cwt. per acre of sulphate of ammonia is significant. Double this dressing has not effected a significant further increase.

(2) This increase is not reflected in wheat grown on fallow. It was secured in wheat after oats or after wheat, the response with wheat after wheat being relatively greater.

4. Investigations of Forage Crops and Temporary Pasture grown prior to Wheat in Four-course Rotations.

The declining fertility of the soils in southern Australia that have been devoted to cereal culture in the past is a matter for concern. Losses of organic matter and soil structure as a result of frequent cereal production, involving in particular the continued use of the wheat, bare-fallow rotation, have inevitably led to marked deterioration of tilth and reduced yields of wheat, oats, and barley.

The restoration of these soils depends on the use of longer crop rotations and the seeding of forage crops or temporary pastures to a much greater extent than formerly.

It becomes important, therefore, to ascertain the effects of different seedings that may be employed to facilitate the increased maintenance of livestock on soils previously devoted to wheat production.

In 1937 a series of rotational experiments was commenced to determine the

effects of four different forage crops on the subsequent yields of pasture and of wheat. Each forage crop is followed by grazed temporary pasture and is subjected to feeding off and harvesting as differential treatments. The yield of wheat sown on fallow provides an indication of the changes in fertility brought about by the various forage crops and their management; these changes are compared with those occurring under a standard wheat, bare-fallow system. The rotations are as follows:

A	*B*	*C*	*D*	*E*
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

A basal dressing of 2 cwt. superphosphate per acre is applied to all crops, including the pasture. Half of each plot sown to a forage crop in rotations A–D is harvested for total produce, and in the case of A, C, and D for grain; the other half-plot is grazed.

The yields recorded in 1937 and 1938 were published in the previous report. The results obtained in 1939 and 1940, together with the means for the four years over which the investigation has been in progress, are presented in Table 2 on page 71.

The yields of the forage crops on the grazed sections have been obtained by means of eight 5 x 5 link samples per plot, taken immediately prior to grazing. In the case of the pastures, twelve 5 x 2½ link samples have been taken per plot prior to each grazing.

It will not be possible to draw definite conclusions from this experiment until at least one, and preferably two, full cycles of each rotation have been completed. Although wheat on fallow followed both grazed and harvested forages for the first time in 1940, wheat in all the four-course rotations outyielded wheat in the two-course rotation of fallow wheat.

Of the various forages, peas were outstanding, averaging per acre 47·17 cwt. of air-dry forage, 42·92 cwt. total crop and 32·40 bushels of grain over the four seasons 1937–40. Peas were much less affected by the two dry seasons, 1938 and 1940, than subterranean clover.

Considerable differences in the yield of temporary pasture are already evident. In all cases greater yields were obtained after grazing than after harvesting the previous forage crop. The pasture yielded only 9·28 cwt. after harvested oats, and 15·07 cwt. after grazed oats, compared with 30·28 cwt. after harvested peas and 41·68 cwt. after grazed peas.

The soil in these plots has been sampled to a depth of 18 inches at completion of the growth of the temporary pasture and at the conclusion of the period under fallow. The moisture and nitrogen content of these samples have been determined.

There have so far been only slight differences in soil moisture content due to treatment. Soil nitrate was low at the conclusion of the growth of the pasture, but increased greatly in the subsequent fallow. It then ranged from 10·8 parts per million in the two-course rotation of wheat, bare-fallow to 20·5 parts per million in the four-course rotation, including grazed peas. The values for all rotations in 1939–40 were as follow (G = grazed, H = harvested):

Mean Nitrate Nitrogen (p.p.m.) to 18 inches.

	Rotation									
	A		B		C		D		E	
	G	H	G	H	G	H	G	H	G	H
Under pasture, at completion of growth	5·2	3·6	4·4	4·5	3·9	3·8	4·7	3·8	3·4	2·8
Under fallow, prior to wheat	20·5	17·2	17·2	15·3	13·6	12·5	16·5	11·8	10·9	10·8

5. Combined Rotational and Fertilizer Experiments.

In 1936 and 1937 four rotational systems, each involving a four-course cycle, were commenced on a field arrangement of 16 blocks. The rotations are as follows:

A	*B*	*C*	*D*
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

Rotations B and C were commenced in 1936, and rotations A and D in 1937.

Within each block are 27 plots, seeded or fallowed uniformly according to the rotation and its phase, but the 27 plots in each of the blocks seeded to field crops receive 27 fertilizer combinations, on a 3 x 3 x 3 basis, covering varying levels of phosphate, nitrogen, and lime.

As there are 16 sections of 27 plots each, the experiment is made up of 432 plots. Fertilizers are applied to the wheat and to all stubble-sown crops, but not to the pasture, nor to the fallow. The field crops are harvested for total produce and grain, while the pastures are sampled on each plot for yield prior to being grazed with sheep. The yields of pasture provide a measure of the residual effects from the previous fertilizer treatments.

The results for the years 1936–38 were presented in the last report. The yields recorded in 1939 and 1940, together with the mean yields from the commencement of the experiment are shown in Table 3 on page 72.

The responses have varied materially according to the crop, the rotation, and the season. Superphosphate at the rate of 1 cwt. per acre increased the yield of wheat grown on fallow by eight bushels in 1939, but only by two to four bushels in 1940. In the case of wheat grown on fallow after pasture and peas, dressings of 1 cwt. and 2 cwt. superphosphate per acre actually decreased the mean yield by 2·78 bush. and 5·00 bush. respectively in 1940. Peas responded to phosphate in the first year it was grown, namely in 1937, and in the dry year, 1940, yielding six bushels more for the addition of 1 cwt. superphosphate per acre, but did not respond to phosphate in 1938 or in 1939. The applications of 1 cwt. superphosphate per acre also increased the yield of oats, barley, and wheat sown on stubble by six to ten bushels per acre in 1939, but only by two to six bushels in 1940. Increasing the dressing from 1 cwt. to 2 cwt. per acre of superphosphate has produced only a slight effect on yield.

Nitrogen as sulphate of ammonia did not affect the yield of wheat sown on fallow in the wheat, peas, or in the wheat, wheat rotations in 1939 or 1940, but increased the yield of wheat on fallow by four bushels per acre in the wheat, oats, and in the wheat, barley rotations in 1939. In 1940 decreases were recorded in the case of the latter rotation; no effect was observed in the case of the wheat, oats rotation. The yield of peas was depressed by sulphate of ammonia in each season except the dry year, 1940, in which increases of two bushels per acre were recorded. In contrast to phosphate, and to nitrogen applied to wheat sown on fallow, sulphate of ammonia gave greater increases in 1940 than in 1939, when applied to stubble-sown oats and barley. Dressings of 1 cwt. and 2 cwt. per acre resulted in gains of 15·51 bushels and 21·50 bush. with oats and 9·93 bush. and 13·77 bush. with barley in 1940. Wheat sown on stubble, however, was increased by these dressings only 6·63 bush. and 12·79 bush. in 1939, and 3·21 bush. and 4·99 bush. respectively in 1940.

Lime increased the yield of wheat sown on fallow by approximately two

bushels per acre in 1936 and 1937, and barley sown on stubble was increased by 3·81 bush. in 1936, by 5·48 bush. in 1939, and 2·52 bush. in 1940. Apart from these responses, lime has so far had no other effects on yield.

Residual effects have been measured on the pasture following the second crop of the rotation. The yields of pasture for 1939, 1940, and the period 1938-40 are presented in Table 3, on page 72. There have been responses due to previously applied phosphate, but neither nitrogen nor lime has produced any residual effect on the pasture.

Census studies have been carried out on the wheat and barley crops in rotation C. Increasing dressings of both superphosphate and sulphate of ammonia have increased tillering and the number of ears per foot at harvest in the case of wheat sown on fallow. The effect of sulphate of ammonia was greater in this respect than superphosphate in the case of barley sown on stubble. The other factors studied were not substantially modified by fertilizer treatment. The census analyses are presented in Table 3.

6. Flax Investigations.

The possibility of growing fibre flax and seed of the variety Liral Crown was first tested in South Australia in 1937, when seed imported direct from England was sown. A programme of investigational work was commenced in that season to indicate the optimum time and rate of seeding and fertilizer treatment necessary to secure maximum yields. It was believed that conditions might favour seed production rather than the production of fibre.

The yields recorded in the initial year were particularly good, and demonstrated that fibre of high quality could be produced in addition to the seed. Further trials were carried out in each of the three following seasons, 1938-40, and these confirmed the results of the 1937 trials, indicating that flax could be grown with considerable success under conditions similar to those of the Waite Institute.

The treatments applied in each season are shown in the following table:

Year.	Dates of Sowing (day and month).	Rates of Seeding (lb. per acre).	Fertilizer.*	Replications.	Total Plots.
1937	21–5, 22–6	40, 60, 80, 100	P_2N_0, P_2N_2	4	64
1938	24–5, 22–6	20, 40, 60, 80	P_1, P_2	4	64
1939	23–5, 3–7	20, 40, 60, 80	P_1, P_2	4	64
1940	8–5, 22–5, 5–6	40, 60, 80	Basal $P_{1\frac{1}{2}}$	4	36

* Fertilizer. P = superphosphate. N = sulphate of ammonia.
Amounts per acre: 0, 1, 1½ and 2 cwt.

The detailed results of the trials conducted in 1937 and 1938 were published in the report for those years. The results for 1939, 1940, and the period 1937-40 are presented in Tables 5, 6, and 7, on pages 76, 77, and 78 of this report. The results of this work will be published in the Journal of the South Australian Department of Agriculture.

Yields of hand-pulled flax exceeding 2·5 tons per acre were obtained, with early seeding, in each of the four seasons. In 1939 and 1940, despite unusually dry conditions in the latter season, yields of 3 tons resulted from early seeding with 80 lb. seed per acre.

Late sowings yielded about one-third less flax straw and seed than were produced from the earlier sowings. Seed production was more affected by season and by the rate of seeding than was straw production. Increasing seed rates to a maximum of 80 lb. per acre tended to produce higher yields of straw and

higher percentages of fibre in the straw, but a seeding rate of only 40 lb. per acre gave the highest yields of seed.

Despite unfavourable conditions of seasonal rainfall in 1938 and 1940, the average yield, for four years, of hand-pulled undeseeded straw from all plots sown in May was 54·10 cwt. per acre, included in which was 10·80 bushels of seed. The greatest effects on yield were produced by modifications in the time of sowing, to which the flax crop appears to be very sensitive.

The results suggest that 1 to 1½ cwt. superphosphate per acre is the optimum fertilizer dressing and that the most suitable seeding rate is between 60 and 80 lb. per acre.

Favourable reports as to the quality and percentage of fibre in the straw were received from the Division of Forest Products, Council for Scientific and Industrial Research, which carried out retting and scutching tests on samples from the trials in 1937, 1938, and 1939.

A quantity of 600 lb. cleaned and graded Liral Crown flax seed was presented to the S.A. Flax Investigations Committee for experimental purposes in 1940. A further quantity of 34 bushels of graded flax seed was produced in 1940 for local seedings in 1941.

A flax deseeder was designed and built during 1940 and was employed successfully to treat more than twelve tons of flax in the sheaf. Flax straw grown and deseeded at the Waite Institute proved to be of high commercial quality.

7. Drill Testing Experiments.

In 1938 and 1939 experimental seed drills were tested for uniformity of distribution of seed and fertilizer and the resultant effect on yield.

(1) *Modifications of Seed Distribution.*

A sample drill of each of three types was included:

(A) Standard type of grain feed.*

(C) Improved cup type of grain feed.

(D) Roller type of grain feed.

Three varieties of wheat (Waria, Gluwari, and Seewari) were sown at two seeding rates—30 lb. per acre and 60 lb. per acre—with all three drills and at 90 lb. per acre with drills A and C. The whole was replicated twice.

The area of each plot at harvest was 1/47th acre. The only statistically significant yield difference was the increase in yield with 90 lb. per acre over 30 lb. per acre. As there was no significant difference in yield between the three varieties, only the averages of the three varieties are included in the yield table on page 12.

By measuring the spacing between the adjacent plants along a short distance of each drill row it was shown that the differences in regularity of spacing by the three drills were not sufficiently great to have any commercial application. A study of the plots sown at 30 lb. per acre indicated the following conclusions.

Under the uneven spacing that occurs in drill sowing, the fewer tillers and ears produced by plants at closer than average spacing were almost completely balanced by the large number produced by plants at wider than average spacing. The figures obtained were as follows:

* A type B, similar to A in grain distribution, but with modified plates and stars was also tested for fertilizer distribution.

	Variety.		
	Waria.	Gluwari.	Seewari.
Number plants	2,166	2,469	1,822
Average spacing	3·26″	2·91″	4·00″
*Tillers per plant at average spacing	5·72	4·15	6·82
Total number tillers at even spacing (calc.)	12,395·3	10,234·5	12,430·5
Number tillers at uneven spacing (actual)	12,407	10,338	11,245
*Ears per plant at average spacing	3·56	2·72	3·66
Total number ears at even spacing (calc.)	7,702·1	6,708·9	6,665·6
Number ears at uneven spacing (actual)	7,766	6,723	6,733

* From regression equations.

(2) *Modifications of Fertilizer Distribution.*

The drills included were:

(A) Standard type.

(B) Modified plates and stars.

In 1938, eight replications of these treatments were sown on the a, b, b, a system, in plots of 1/50th acre. A Hard Federation x Gluyas cross was sown at the rate of 60 lb. per acre and superphosphate was applied at the rate of 84 lb. per acre. The only difference in treatment was the different method of distribution of superphosphate.

Drill B produced a significantly higher yield than drill A (*vide* following table), and the experiment therefore was repeated in the following year, using (a) the variety Waria at 60 lb. per acre; superphosphate at 175 lb. per acre, and (b) the variety Gluwari at 60 lb.; superphosphate at 106 lb. per acre.

(1) Modifications of Seed Distribution.

Yields of wheat in bushels per ac. (means of 3 varieties).

	30 lb. per ac.	60 lb. per ac.	90 lb. per ac.
Drill A	33·10	33·80	38·39
Drill C	34·39	36·44	39·88
Drill D	32·64	36·47	—

(2) Modifications of Fertilizer Distribution.

Yields of wheat in bushels per ac.

	1938.	1939.	
	Hard Federation × Gluyas.	Waria.	Gluwari.
Drill A	36·70	28·97	29·52
Drill B	40·18	29·81	30·28
Difference	+ 3·48*	+ 0·84*	+ 0·76
S.E. (Difference)	*0·37*	*0·31*	*0·62*

* Significant difference.

2. PLANT BREEDING AND GENETICS.

Plant breeding activities are concerned with the production of improved strains of cereals, pasture grasses, legumes, and vegetable crops.

1. Cereals.

(1) *Wheat.*

Wheat is economically the most important cereal crop in southern Australia, and consequently more attention has been paid to wheat breeding than to the breeding of other crops.

The long-term objective of the wheat-breeding programme is the production of varieties adapted to the special requirements and range of South Australian soils and climatic conditions and superior to existing varieties in yielding ability, in resistance to drought and disease, and in baking quality. The following account reports progress towards the attainment of these objectives during 1939 and 1940.

Wheat breeders depend to a large extent on the environment to assist in the selection of desirable strains. The 1939 and 1940 seasons were valuable in this respect. During the wet year of 1939 strains were selected for resistance to leaf and stem rust and for stiffness of straw. In contrast, 1940 was unusually dry and the crops were free from rust. Hot, dry winds in early December caused considerable shattering of grain. Selection of strains which could withstand a dry spring and were free from shattering of grain were the chief features of the year's work on wheat.

(*a*) Named varieties. Encouraging reports have been received from farmers growing the new Waite Institute wheats—Seewari, Gluwari, and Waria. Seewari was outstanding in 1940 in that it outyielded standard varieties in bulk sowings at Keith, Lowalde, Saddleworth, Hilltown, Wirrabara, Andrews, and Ungarra.

(*b*) New crossbreds. Certain new crossbreds, should they continue to show promise, will be named in the near future. Of these Nabawa x Hope is worthy of note in that it is highly resistant to leaf rust, stem rust, flag smut, and mildew, and is moderately resistant to loose smut and bunt. The strain approaches the standard varieties in yielding ability and is likely to outyield them in years when diseases, especially the rusts, are prevalent. In 1939, a year favourable for rust at the Waite Institute, the yield of Nabawa x Hope was 109 per cent. of that of Ranee; in 1940, a year free from rust, its yield was 92 per cent. of Ranee and 103 per cent. of Nabawa. At other centres in 1940 it yielded 98 per cent. of Ranee at Lowalde and 104 per cent. at Saddleworth.

Other crossbreds of merit are two strains of Nabawa x Hard Federation and one each of Ghurka x Nabawa, Ghurka x Gluyas, and [(Florence x Nabawa)^1 x Free Gallipoli]^1 x Dundee.

(*c*) Pedigree rows. Pedigree rows, of which 8,000 to 10,000 are sown annually, are selected for apparent yielding ability, desirable agronomic characters and resistance to disease. Approximately 70 per cent. of the rows from the fourth generation onwards sown in 1940 were selected for resistance to the rust diseases in 1939. With a large bulk of the material resistant to rust, highly susceptible check rows and guard rows have to be sown to facilitate the natural spread of the disease.

(*d*) Yield trials. Selected strains are sown in yield trials not earlier than the fifth generation from crossing. The first drill-sown yield trial to which any strain is subjected consists of 1/295th acre plots, 2 ft. 4 in. wide and 66ft. long, unreplicated because of the limited quantity of seed, but with a check plot sown every fifth plot. The trial involves 300 plots.

Crossbred strains selected for desirable agronomic characters, and which yielded equal to or better than the standard variety Ranee in the 1940 trial, are listed below, together with the percentage infection with flag smut in 1940 and the rust ratings of 1939.

The second yield trial, in which selected strains from the first yield trial are tested, consists of 1/295th acre plots replicated in a cubic lattice design of 125 strains arranged in 75 blocks of 5 plots. This design for testing a large number of varieties was first used in 1940. Results were satisfactory and the trial was convenient to handle. Small plots and pathways between plots gave an exaggerated yield and a considerable border effect. However, in 1940 strains sown in 1/50th acre plots without pathways were also included in 1/295th acre cubic

lattice design plots. Although there was a large difference in yield in favour of the 1/295th acre plots, the order of yield was, with one minor exception, the same in both trials.

Strain No.	Crossbred.	1940. Yield % Ranee.	1940. Flag smut %.	1939. Leaf rust 0–5.	1939. Stem rust 0–5.
1	Dundee x Ranee	109	3	4	4
2	Dundee x Ranee	100	15	4	4
3	Dundee x Ranee	109	3	4	4
6	Kenya Crossbred x Ranee	100	25	3	0
9	Kenya Crossbred x Ranee	100	3	3+	0
16	Ghurka x Dundee	100	0	3	3
17	Ghurka x Dundee	103	0	3	3
32	Kenya Crossbred x Ghurka	109	0	3	0
33	Kenya Crossbred x Ghurka	106	0	3	0
34	Kenya Crossbred x Ghurka	109	0	3	0
39	Ghurka x (Pusa 4 x Ford)[1]	112	0	3	1
53	Kenya Crossbred x Ford	101	0	3	0
54	Free Gallipoli x (Pusa 4 x Ford)[1]	101	50	4	4
57	Kenya Crossbred x Dundee	101	27	3	0
59	Kenya Crossbred x Dundee	101	3	3	2
101	Kenya Crossbred x Dundee	126	5	3	0
102	Kenya Crossbred x Dundee	106	15	3	0
103	Kenya Crossbred x Dundee	115	5	3	0
104	Kenya Crossbred x Dundee	121	25	3	1
109	Kenya Crossbred x Dundee	121	0	3	1
	Ranee	100	50	5	5

In the following table are given yields and ancillary data for those crossbreds and varieties which yielded within the error limits of the yield of Ranee. Additional varieties in the same trial are included for comparison.

The success of [(Florence x Nabawa)[1] x Free Gallipoli] x Dundee and the various Ghurka crossbreds in this test suggests that after further testing one or more of them may be useful varieties. Strain number 445 is resistant to flag smut and mildew and is of good baking quality.

Strain Symbol.	Crossbred.	1940 records. Yield, bush. per ac.	Days to heading.	Shatter (rating 0–5)	Flag smut %.	Bunt (angles 0–90)	1939 records. Leaf rust 0–5.	Stem rust 0–5.	Mildew 0–5.
253	Nabawa x Hard Federation	56·1	108	0+	14	51	5	5	0
435	[(Florence x Nabawa)[1] x Free Gallipoli][1] x Dundee	55·7	112	0	28	39	5	4	0
124	Ghurka	55·1	118	0	7	29	3—	1	0
445	[(Florence x Nabawa)[1] x Free Gallipoli][1] x Dundee	54·9	113	0	0	46	4	3	0
415	[(Florence x Nabawa)[1] x Free Gallipoli][1] x Dundee	54·7	112	0	13	55	5	4	0
154	Ghurka x Nabawa	54·6	113	0	43	62	4	4	0
542	Ranee	53·9	114	0	50	44	5	5	5
135	[(Florence x Nabawa)[1] x Free Gallipoli][1] x Dundee	53·6	113	0	7	49	4	3	0
213	Nabawa x Hard Federation	53·6	106	0	23	60	5	5	3
114	Ghurka Selection	53·1	121	0	—	—	–	–	–
324	Ghurka x Gluyas	52·5	117	0+	3	54	3	2	1
144	Ghurka x Nabawa	52·5	120	0	8	53	4—	2+	2
131	[Nabawa x (Nabawa x Hope)[1]][1] x Dundee	52·3	115	1	3	69	3	5—	2
117	Ford (S.A.)	52·0	117	1	31	53	3	4	2—
234	Ghurka x Gluyas	51·8	112	0	78	64	5	4	1
214	Ghurka x Nabawa	51·7	117	0	0	61	3	3	0
554	Seewari	51·7	118	0+	43	60	4	3	2
151	Sword	50·7	115	0	6	69	5	3	1

PLOTS OF NEW CROSSBRED WHEATS AT THE WAITE INSTITUTE, 1940.

Strain Symbol.	Crossbred.	1940 records. Yield, bush. per ac.	Days to heading.	Shatter (rating 0–5)	Flag smut %	Bunt (angles 0–90)	1939 records. Leaf rust 0–5.	Stem rust 0–5.	Mildew 0–5.
215	[Nabawa x (Nabawa x Hope)1] x Dundee	50·5	116	0	9	55	3	4	1
121	[Nabawa x (Nabawa x Hope)1] x Dundee	50·3	117	0+	13	53	4	4	1
123	Dundee	50·1	114	0	8	48	4	4	0
134	Ghurka x Nabawa	49·9	113	1	4	51	5	3	0
142	Nabawa x Hope	49·2	113	0+	0	34	1—	0	0
	Variety.								
334	Magnet	48·7	123	0+	58	53	–	–	–
524	Federation	44·1	117	1+	69	54	5	5	5
122	Fedweb I	42·4	123	0+	—	—	–	–	–
444	Nabawa	42·0	114	0+	2	51	5	3	0
322	Eureka II	40·9	114	0	17	52	–	–	–
543	Aussie	40·0	109	2	55	65	–	–	–
242	Bencubbin	39·4	116	1	2	42	5	3	0
335	Hofed I	37·9	118	2	33	55	–	–	–
353	Gular	37·7	106	0+	22	64	5	3	0
421	Waratah	35·8	113	3	59	55	5	3+	1
255	Ford (N.S.W.)	27·6	115	4	13	36	–	–	–
454	Florence	24·8	107	4	2	20	–	–	–

Standard deviation of mean yields (V211–V111)* = 2·53 bush. per ac.
(V122–V111) = 2·60 bush. per ac.
(V222–V111) = 2·61 bush. per ac.

* Groups for test of significance.

The third yield trial, in which selected strains may be retained for a number of years, consists of replicated 1/50th acre plots sown adjacent to each other. The outside rows are cut out prior to harvest so that the results represent true field yields. In 1939 two groups, each of 10 strains, arbitrarily classified into early and late maturing types, were sown in randomized blocks. The 1940 trial was a balanced incomplete block design of 21 varieties arranged in 21 blocks of five plots each.

A summary of yields of strains selected for further testing in 1941 is given below:

	Yield as a percentage of yield of Ranee. 1939.	1940.
Nabawa x Hard Federation (37–309)	112	98
Nabawa x Hard Federation (37–443)	121	89
Seewari (33–101)	105	104
Nabawa x Hope (37–76)	109	92
Ghurka x Nabawa (38–301)	—	95
Ranee	32·8 bush.	39·8 bush. per ac.

Strains which yield satisfactorily in the above trials for one or more years are then tested in country districts, either as replicated trials or as observation plots. Replicated trials have been conducted in the country at Yurgo, Saddleworth, and Pallamana. The dry season of 1940 resulted in a crop failure at Pallamana.

Yields of promising strains in these trials, expressed as a percentage of the yield of the check variety Ranee, are as follows:

	Lowalde. 1939.	Lowalde. 1940.	Saddleworth. 1940.
Seewari	106	114	104
Gluwari	122	108	81
Nabawa x Hard Federation	116	106	102
Nabawa x Hope	—	98	104

(*e*) Disease resistance of wheat.

(i) Stem and leaf rust. Stem rust (*Puccinia graminis tritici* race 34), leaf rust (*Puccinia triticina* races 16 and 26), and mildew (*Erysiphe graminis*) were severe during 1939, and it was possible to make many selections possessing resistance to all three diseases. These selections are all derived from Hope crosses, the first of which were made in 1928.

Although stem and leaf rusts were absent during 1940, excellent infections were obtained in the flag smut and bunt trials. The 125 advanced crossbreds and varieties of the cubic lattice yield trial were tested in a similar design for flag smut and bunt resistance.

(ii) Flag smut. The majority of crossbreds were shown to be highly resistant to flag smut (*Urocystis tritici*), having 0–3 per cent. infected plants in comparison with susceptible varieties like Free Gallipoli (64 per cent.) and Federation (69 per cent.). Several strains of Nabawa x Hope, Nabawa x (Riverina x Hope), Nabawa x (Nabawa x Hope) and (Gluyas x Hope) x Nabawa, which are now in yield trials, possess resistance to leaf rust, stem rust, mildew, and flag smut. Promising strains of Ford x Hard Federation, possessing high yielding ability and superior baking quality (*vide* previous reports) have had to be discarded solely on account of flag smut susceptibility, ranging from 71 to 85 per cent. In the 1940 tests certain strains derived from crosses between the flag smut resistant wheats, Ghurka and Nabawa, proved to be susceptible, indicating a transgressive segregation of flag smut susceptibility. It is planned to study the F_3 segregation of this and other crosses in an attempt to identify the genes responsible for resistance in our standard varieties.

(iii) Bunt. In contrast with flag smut, the majority of crossbreds proved to be susceptible to bunt (*Tilletia tritici* and *Tilletia levis*). Florence (12 per cent.) and Hope (4 per cent.) were highly resistant, and certain Nabawa x Hope strains were partially resistant (30–40 per cent.), but all other varieties, including a strain of the American Turkey and the durum wheats, Huguenot and Gaza, were highly susceptible (60–80 per cent.). Attempts are being made to separate physiologic races from the spore collection used.

(iv) Mildew. A study was commenced in 1940 of the inheritance of resistance to mildew (*Erysiphe graminis*) in *T. vulgare* and 28 chromosome wheats. Some evidence was obtained which indicated a single factor difference between Sonora (resistant) and Federation (susceptible) with dominance of resistance.

(*f*) Genetics and cytology of wheat. Work on the inheritance of awns, which has been in progress for some time, is being extended to include the 28 chromosome wheats.

A detailed study is being made of an abnormal speltoid which, under certain environments, is polycarpic and without anthers, while at other times it may be fertile with extra flowering glumes and with a variable number of anthers. Heads of both types may often be found on a single plant. Cytologic and genetic investigations of various speltoid types are being continued in an effort to understand something of the origin of such aberrant types.

(2) *Oats.*

Crosses have been made between local varieties and imported varieties resistant to rust and smut. The objective of these crosses has been to combine, in one or more varieties, resistance to these diseases with desirable agronomic characters.

An oat variety trial, comprising five randomized replications of four varieties was sown in 1939 with the following results:

Yields per acre of total produce and grain.

1939.

Variety.	Early Burt.	Mulga.	Algerian.	Huskless.
Total produce (cwt.)	65	63	74	70
Grain (bush.)	68	65	59	27

A chemical investigation of huskless and common husked oats did not support the suggestion that the huskless oat was more liable than ordinary varieties to become rancid on storing. Acidity values in c.c. of N/10 alkali per gm. on both oven-dry and air-dry samples ranged from 0·24 to 0·55 for huskless oats and 0·26 to 0·50 for ordinary oats.

(3) *Barley: Smooth-Awned Feed Barley.*

Four smooth-awned strains obtained from a cross between the variety Cape and an imported smooth-awned variety were tested for yielding ability in a replicated trial sown on stubble in 1940. The yields were: Strain I., 26·44 bushels; Strain II., 25·75 bush.; Cape, 23·69 bush.; Strain III., 22·51 bush., and Strain IV., 22·06 bush. One of these strains will be named in the near future.

(4) *Linseed.*

Linseed for the production of linseed oil is a possible alternative crop to wheat in the 18–20 inch rainfall belt of South Australia. Information on the adaptability of imported varieties was obtained from a trial involving ten varieties sown in 1940. The results showed two to be outstanding—Punjab, which yielded 15·75 bushels per acre, and Abyssinian, which yielded 13·64 bushels. Loss of seed due to boll-worm (*Heliothis armigera* Hb.) attack after flowering was considerable. An estimate of the loss obtained by harvesting and examining 14 foot-length samples from each plot for damaged bolls, gave an average loss over all plots of 26·9 per cent. Varietal differences in the percentages of grain damaged were not significant.

Samples of seed of each variety of linseed were submitted to Messrs. Meggitt Ltd., Parramatta, New South Wales, for analysis and report. We are indebted to them for the analyses of oil content and oil quality reported in Table 7 on page 78.

A linseed breeding programme was initiated in 1940 by crossing the high-yielding variety Punjab with other varieties possessing such desirable characters as medium tall straw and resistance to flax rust. Punjab possesses very short straw and is susceptible to rust. Should the linseed-growing industry develop in Australia, this breeding work will be accelerated.

2. Pasture Plants.

(1) *Perennial Rye-grass.*

Breeding work with perennial rye-grass, discussed in previous reports, involves the production of an improved strain for local conditions. The work has been enlarged to include a sward trial with seed of 120 intercrossed parent plants selected from approximately 20,000 plants. The objective is to assess the value of the progeny of these 120 selected parent plants and to use those parents which give productive progeny as the basis of an improved strain. The sward trial consists of 375 plots with 125 strains arranged in a cubic lattice design.

(2) *Creeping Lucerne.*

The breeding of a creeping type of lucerne for grazing purposes is progressing. Bulk sowings were made in 1940, and swards were established with outcrossed

seed from single creeping-type plants. These swards will indicate the value of these single plants as future parent plants in building up a desirable strain. A bulk collection of seed from plants sown in 1938 as 3,000 single plants showed 70 per cent. of creeping types. Seed of further selections of desirable plants from this material will be sown in 1941. Progress in the breeding of creeping lucerne is retarded by the fact that the creeping habit of seedling plants is not evident until the second year of growth. Results to date are promising in that 70 per cent. of the progeny of selected creeping types are creeping. Seed from creeping plants has been distributed to country centres for trial purposes.

(3) *Prairie Grass.*

Investigations on prairie grass reported in 1938 are being continued, and selected material is being multiplied for seed production. Tests with selected strains are being carried out in comparison with forage crops, grasses, and legumes as temporary pastures established alone and in conjunction with harvested crops.

(4) *Subterranean Clover.*

Following the selection and multiplication of outstanding strains of varying maturity, a replicated sward trial with Dwalganup, Mulwala, Seaton Park, Bacchus Marsh, Mt. Barker, and Tallarook strains of subterranean clover (*Trifolium subterraneum*) was sown at the Waite Institute in 1939. A satisfactory establishment of all strains resulted, but that of Seaton Park was significantly lower than the others, as also was its yield for the first season. The climatic conditions in 1939 were very favourable for seed production, and the three later strains (Bacchus Marsh, Mt. Barker, and Tallarook) produced a dense mass of seedlings in the following autumn. The three earlier strains set a high proportion of hard seed and produced fewer seedlings in the following year. This was reflected in the yields of herbage, which were significantly greater in the Bacchus Marsh, Mt. Barker, and Tallarook strains than in the Dwalganup, Mulwala, and Seaton Park strains. Within each group the three strains did not differ significantly from one another.

In order to acquire further information on the adaptability of the various strains to different environments, a further trial, comprising four strains of subterranean clover (Dwalganup, Mulwala, Seaton Park, and Bacchus Marsh), together with two species of *Medicago* (*M. tribuloides* and *M. obscura*) was commenced at Salisbury in 1940, but under the unfavourable climatic conditions of that season the production and seed setting of all strains were very low.

Several strains, including two white-seeded early-flowering types from Western Australia, proved superior in vigour and seed setting to Dwalganup used as a check strain in single plant rows in 1939. A further test in small plots, made in 1940, showed that the seed setting of Dwalganup was significantly higher than that of either the two white-seeded types, or the group of late-flowering strains, including Mt. Barker, Tallarook, and Krongart. Further investigations of the white-seeded strains are being carried out.

(5) *Strawberry Clover.*

The previously selected strains of strawberry clover (*Trifolium fragiferum* L.) have been under observation for two years at Meadows on a low-lying area of black soil where the Palestine strain, which has since been placed on a commercial basis, has shown outstanding development and capacity to withstand waterlogging throughout the winter. No additional selection work has been carried out.

(6) *Barrel Medic.*

Barrel medic (*Medicago tribuloides*) has proved its adaptability to certain environments in which the high available lime content of the soil appears to render it unsuitable for the growth of subterranean clover. Its ability to grow and seed well under rainfall conditions too low for the persistence of subterranean clover is also of importance. Strains were collected and grown under single plant conditions at the Waite Institute during 1939 and of these, thirteen types were selected on the basis of desirable burr type and for vigour of development. One of these was a strain collected at Noarlunga which has been available on the commercial market. A sward trial of these strains is being conducted.

3. Vegetables.

(1) *Beans.*

In 1939 studies on the inheritance of resistance to halo blight of beans (*Pseudomonas medicaginis* var. *phaseolicola*) were commenced. F_3 seed is now ready for testing. The parents being used are Canadian Wonder and Premier, which are susceptible, and Burnley Selection and an unnamed selection from Premier, which are resistant.

(2) *Tomatoes.*

In co-operation with the Department of Plant Pathology, work is being continued in the breeding of tomatoes for resistance to leaf mould, *Fusarium* wilt, and spotted wilt. Further details will be found in another section of the report (page 34).

3. PASTURES.

Investigations concerning the ecology of pastures and practical pasture improvement have formed an important part of the work in agronomy and agrostology since 1927. These investigations, which have been described in detail in previous reports, owe much of their early development to co-operative assistance from the Empire Marketing Board and the Council for Scientific and Industrial Research. The latter has maintained its interest in the work relating to mineral deficiencies and pastures. The discovery that minor element deficiencies are widespread in the higher rainfall coastal areas of southern Australia has enhanced the significance of this work.

It has been found in practice that a wide scope exists for pasture improvement, and increasing interest has been shown by agriculturalists in the establishment of seeded pastures. Projects have dealt in particular with the response of pastures to fertilizer treatment, the testing of pasture species and strains, the design of seeds mixtures, the improvement of pasture plants by selection and breeding, associated growth between legumes and non-legumes, land improvement and development, pasture experimental technique and the management of pastures.

1. Top-dressing of Natural Pastures.

Investigations of natural pastures formed an important phase of the initial work on the mineral content of pastures. The first experiment, designed in 1925 to determine the effects of equivalent dressings of phosphate (40 lb. P_2O_5 per ac.) in the form of superphosphate, basic slag, rock phosphate, and the effect of nitrate of soda (78 lb. per ac.) added to the superphosphate, has been continued as a permanent investigation. The effects of each fertilizer on the yield of herbage and the stock-carrying capacity over sixteen years are summarized in Table 8 on page 78.

Regression analysis of the relationship between the annual yield of the pasture and the monthly rainfall throughout the season indicated that the yield of natural pasture for the season was largely predetermined by the amount of autumn and early winter rainfall.

In 1940 use was made of these plots to maintain separate flocks of Merino wethers, on a 5-weekly cycle of rotation, throughout the greater part of the growing season. Corresponding flocks were maintained, for comparative purposes, on adjoining areas of seeded pasture, on one of which hay is cut and fed back to the sheep. It is proposed to confine these flocks of sheep, of which there are eight, to the types of pasture represented by the experimental plots, with a view to assessing their effects on the sheep over a period of seasons.

The effect of phosphatic fertilizers on the carrying capacity, nutritive value, and the mineral content of natural pastures at the Waite Institute and the Government Experimental Farm, Kybybolite, has been investigated in past seasons and was described in the previous report.

2. Introduction and Testing of Cultivated Pasture Plants.

Many species and strains of herbage plants have been introduced from abroad by the Waite Institute; close contact is also maintained with the Plant Introduction Section of the Division of Plant Industry of the Council for Scientific and Industrial Research. Approximately 4,000 samples have been received and the majority of these tested under field conditions at the Waite Institute.

Grasses of economic importance from the drier regions of the United States were introduced for testing in 1940. Difficulty was experienced in securing germination of the seed in some species. Species of clover (*Trifolium*), together with some trefoils (*Medicago* spp.) were also introduced from the United States and Turkestan. These were grown as single plants in 1940, and a number showing superior vigour and other desirable features were selected for seed multiplication and further testing in swards.

Phalaris tuberosa, Wimmera rye-grass, lucerne, subterranean clover, and barrel medic have so far proved of outstanding value for cultivated pasture at the Waite Institute. Selected strains of prairie grass may also find a place in temporary pastures and are under test with this end in view.

Giant star grass (*Cynodon plectostachyum*) was tested in 1940 and its reputed capacity for rapid development of leaves and stolons confirmed. Reports that this species was liable to develop poisonous properties were not substantiated by limited feeding tests. It does not appear to be so drought-resistant as ordinary couch grass (*C. dactylon*).

A form of rhizomatous lucerne characterized by an especially prostrate habit of growth, and collected originally from a sandhill region in southern Turkey by the United States Department of Agriculture, was successfully introduced from America as vegetative material. This has been added to the collection of creeping lucerne types maintained at the Waite Institute for breeding purposes.

Forms of Kikuyu grass were introduced from Kenya in 1940 for the purpose of making a study of variability within this species and determining whether viable seed could be produced in the South Australian environment. Seed-producing types have been isolated in considerable number and will be utilized for multiplication and further study in 1941-42.

3. Comparison of Top-dressed, Natural, and Seeded Pastures at Kybybolite.

The relative value of top-dressed sown and natural pastures was investigated, in co-operation with the Department of Agriculture at the Experimental Farm,

Kybybolite, over a five years' period, 1935–40. Four blocks each of Wimmera rye-grass + subterranean clover, *Phalaris tuberosa* + subterranean clover, and top-dressed natural pasture were each grazed in rotation with standard flocks of 40 comeback ewes. Additional sheep were introduced whenever surplus feed was considered to be available. Deaths during the course of the experiment reduced the basal sheep numbers to 35 on the natural pasture and to 38 on each of the sown pastures. The live-weights of the ewes were recorded each month.

The pastures were compared on the basis of their carrying capacity, botanical composition throughout the growing season and the yield of oven-dry herbage cut at the end of seasonal growth, together with the live-weight gains of the sheep, the weight and value of the wool, and the percentage and weight of lambs produced. The detailed results of the experiment are presented in Table 12 on page 82.

The carrying capacities of both sown pastures were significantly higher over the full period of the experiment than that of the natural pastures. The mean figures for Wimmera rye-grass + subterranean clover, *Phalaris* + subterranean clover, and natural pasture were 3·76, 3·89, and 3·18 sheep per acre per annum respectively.

All pasture types deteriorated to some extent throughout the period of the experiment through the entry of annual grasses, thistles, and other inferior plants, but the yield of oven-dry herbage cut at the end of seasonal growth on the Wimmera rye-grass + subterranean clover pasture was significantly higher than that of the natural pasture in four of the five years, while that of the Phalaris + subterranean clover pasture was significantly greater than the latter in only two of the five years.

The superior feeding value of the sown pastures was shown by the higher mean live-weight attained on these pastures over the full period of the experiment.

The mean weight and value of the wool per sheep from the flocks on sown pasture was higher than on natural pasture in 1936 and 1937, but the three flocks were not significantly different in these respects in the following two years or over the full period of the experiment. The weight and value of the wool produced per acre were greater on the sown pastures than on the natural pasture over the five-year period of the experiment.

The ewes in the two flocks on seeded pasture were characterized by a higher percentage lambing during each season. The lambs from the Wimmera rye-grass + subterranean clover flock were of higher mean weight at weaning and recorded higher mean daily increases in weight than the lambs from the remaining two flocks in 1938, but this was not repeated in 1939.

4. Response of Seeded Pastures to Fertilizers.

(1) *The Application of Nitrogen to a Seeded Pasture Mixture under Hay and Grazing Treatment at the Waite Institute.*

Investigations of seeded pastures in 1927–29 led to the establishment at the Waite Institute in 1930 of a permanent mixture of Wimmera rye-grass, certified New Zealand perennial rye-grass, *Phalaris tuberosa* and early-flowering subterranean clover, which has been maintained under varying conditions of management for a period of eleven seasons.

A basal dressing of 2 cwt. superphosphate per acre has been applied each year to a total number of sixteen plots, of which eight have received in addition 2 cwt. sulphate of ammonia per annum.

The pasture was dominated by Wimmera rye-grass in the first season and perennial rye-grass in the second. The following year perennial rye-grass, which suffered heavy mortality in the second summer, was succeeded to a substantial

degree by *Phalaris tuberosa,* and this grass has dominated the pasture for the remaining period.

It was found that the pasture responded to nitrogen slightly in the year of establishment on fallow, and actively in the second season. Thereafter the yields tended to be depressed by nitrogen, although in recent years the grazed sections have responded slightly to nitrogen. The mean annual differences due to the application of sulphate of ammonia under various forms of management have been as follows:

A. Cutting 3 to 4 times annually, — 2·34 cwt. B. Cutting followed by grazing, + 3·14 cwt. C. Grazing, + 2·03 cwt. D. Cutting once as hay, + 0·97 cwt. dry matter per acre.

The addition of sulphate of ammonia reduced, in all cases, the percentage and amount of clover in the pasture. Under systematic cutting (treatment A) clover gradually attained dominance, even on plots receiving sulphate of ammonia; with the three remaining treatments clover has been prominent only in some seasons. The average yield under grazing is higher than under treatments A, B, and D, presumably as a result of the return of nutrients and because grazing imposes less drastic effects on the sown grasses than cutting. Perennial rye-grass has become most prominent under the cutting and grazing treatments, whereas *Phalaris* produced its highest yields where cut for hay.

At the conclusion of the tenth year an analysis of the relationships between the annual yield of the pasture and rainfall was attempted, but no significant correlation could be established between annual, seasonal, or monthly rainfall and yield as had been obtained with natural pastures (page 20). It is suggested that the perennial nature of the dominant species, *Phalaris tuberosa,* and its capacity to obtain accumulated moisture from the subsoil have a bearing on this result; the relationships between botanical composition, seasonal yield, moisture, and the available supply of plant nutrients in the soil are probably complex and require further detailed study before satisfactory conclusions can be drawn.

(2) *The Effect of Superphosphate and Surface Cultivation on a Seeded Pasture Mixture at the Waite Institute.*

To determine the effects of varying quantities of superphosphate, with and without surface cultivation, on the yield and botanical composition of a permanent seeded pasture grown at the Waite Institute, an investigation was commenced in 1937 as a supplement to the pasture management trial described later.

This investigation has now been carried out over four seasons under six-weekly grazing by Merino sheep. It has been consistently demonstrated that an annual dressing of 1 cwt. superphosphate is of significant benefit to the pasture, despite previous phosphatic fertilization. Higher dressings produced additional responses in 1937 and 1939, but not in the two dry seasons, 1938 and 1940. Cumulative effects of previously applied phosphate have been marked, and it is doubtful whether the application of superphosphate in a dry season such as 1940 would be economically warrantable, where phosphate had previously been supplied. There has been no response by the pasture to surface cultivation.

Detailed results of this experiment are given in Table 11, on page 81.

5. Investigations on Pasture Management.

The grazing experiment dealt with in the previous report has now entered its fifth year, and the earlier findings are, in general, substantiated by the data for seasons 1939–40 (Table 12, on page 82). It has still been possible to graze at the rate of six wethers to the acre throughout the year on 6–9 weekly cycles, although the 1940 season was abnormally dry. Increasing the stocking rate and cutting

for hay have both tended to increase the amount of weeds in the pasture, probably as a result of partial weakening, with resultant lowered competitive effect on the part of *Phalaris tuberosa*. The infrequent cycles of grazing (6–9 weeks) have tended to produce opposite effects in the case of the perennial grass, resulting in a lowered weed content where hay is not cut.

While this experiment is in progress two management trials are also being conducted, one at the Waite Institute and the other at the Experimental Farm, Kybybolite, to investigate the effects of different forms of grazing management on production from Merino and crossbred wethers. These trials, each 21 acres in area, were sown in May, 1939, with a seeds mixture of ½ lb. Wimmera rye-grass, 3 lb. *Phalaris tuberosa,* and 5 lb. subterranean clover. Following uniform treatment in the seeding year, each pasture was sub-divided into 16 separately-fenced 1¼ acre plots. On these, flocks, one half of which are Merino and the other Romney Marsh x Merino sheep, are grazed (a) continuously, without cutting for hay, (b) continuously, with two of the plots cut for hay in spring and fed back in summer, (c) rotationally, at 8-weekly intervals in autumn and winter and 4-weekly intervals in spring and summer, without cutting for hay, and (d) rotationally, as in (c) but with hay cut and fed back as in (b), thus providing a 2-weekly cycle in spring. Grazing commenced at each centre in May, 1940, with a uniform stocking rate over all treatments of 4 sheep per acre, but owing to the dry conditions at Kybybolite during the spring and summer months, the rate was temporarily lowered to 2·4 sheep per acre. The weights of the sheep are recorded each month, and in addition data is taken on their wool yields and counts. The crossbreds, as expected, have made greater live-weight gains at both centres than the Merinos, but after only one year it is too early for any definite conclusions to be drawn.

6. Investigations on Pasture Management—Yudnapinna Station.

Investigations into problems of the drier pastoral lands in South Australia have indicated that there is an immediate need for information relating to the management of pastures still dominated by perennial shrubs, such as saltbush (*Atriplex vesicarium*) and bluebush (*Kochia sedifolia* and *K. Planifolia*). Deterioration of these pastures, owing chiefly to overgrazing by sheep, has reached a stage where approximately only 25 per cent. of the original perennial bush cover remains. Experimental data concerning the effects of varying pasture management should enable practical methods to be devised whereby the surviving areas of perennial bush may be preserved.

In 1940 a grazing management trial was designed for myall-bluebush country on Yudnapinna Station, 50 miles north-west of Port Augusta. The difficulties confronting such an experiment on an area receiving low and exceedingly variable rainfall are many, and these were considered at length before final plans were adopted.

The present carrying capacity of the whole station (1,390 sq. miles) is approximately 22 sheep per square mile, and any worthwhile grazing experiment under these conditions involves the provision of fencing and watering facilities for paddocks of sufficient size. This obstacle was met and overcome by the further generosity and co-operation of Mr. J. T. Mortlock and the Yudnapinna Pastoral Company.

The design of the experiment accommodates fourteen paddocks, each of 160 acres, and in addition two spelling paddocks aggregating 750 acres. Treatments include three rates of stocking: light (24 sheep per square mile), medium (48 sheep per sq. mile), and heavy (72 sheep per sq. mile), and four types of grazing—continuous, spelled after effective rains, spelled during drought, and spelled during the period between cessation of growth and the inception of drought condi-

tions. Of the remaining two paddocks of 160 acres, one is shut off entirely from sheep as a control area, while the other provides for a test of the effects on the pasture and on the sheep of bore water for drinking compared with water from a surface catchment which is used in the other plots. The stocking rates are heavier than would be employed on a large scale, owing to the small paddocks, which make for even grazing, and the quality of the pasture, which is above the general average for the station.

Estimations of all edible vegetation will be carried out yearly by a weight-estimate method involving 64 sample points, spaced on a grid pattern, in each paddock. Estimations are made on a circular area of 1/100th acre circumscribed about each sample point. The numbers of each species are recorded and the respective weights of edible vegetation estimated by eye. To ensure accuracy, frequent checks are made by estimating and then clipping the herbage from temporary plots. A preliminary examination carried out on all paddocks in 1940 indicated that the standard error of samples estimated by this method is less than 10 per cent., which is well below the limit of accuracy required, as the differences due to treatment are expected to be considerable.

Provision has been made for photographs to be taken at two fixed points in each paddock from time to time during the course of the experiment.

The installation of all fencing and watering facilities was completed by the end of 1940. A resident stockman is to be appointed, and sheep will be allocated to the respective plots early in 1941.

7. Investigations Relating to Soil Erosion and Pasture Regeneration.

(1) *Pastoral Areas.*

Investigations of soil erosion and the regeneration of pastures under the terms of the Ransom Mortlock Trust have become resolved into two main objectives.

The first of these involves the management of existing perennial shrub pastures and is discussed in the preceding section of this report. The second is more difficult to attain and requires the regeneration of perennial plants on areas which have been denuded of their natural cover by various agencies, particularly overgrazing by sheep. Theoretically this objective may be attained either by natural regeneration or by artificial reseeding.

Natural regeneration is likely to prove an extremely slow process under the conditions of light and variable rainfall, associated with a high rate of evaporation, which characterize the pastoral areas. Data from chart quadrats commenced at Yudnapinna Station early in 1939 bear out this hypothesis, even where full protection is afforded from sheep and rabbits.

Experiments on artificial reseeding of denuded areas were undertaken at Yudnapinna in 1939 and at Blanchetown—a pastoral centre with slightly better rainfall—in 1940. Saltbush (*Atriplex vesicarium*) and bluebush (*Kochia sedifolia*), with various other species, have been seeded on cultivated soil; at Blanchetown contour furrows were employed to collect and conserve additional moisture. Sufficient moisture for the establishment of young seedlings appears to be the critical factor in any attempt at artificial reseeding, and unfortunately seasonal conditions proved unfavourable, particularly in 1940, which was characterized by severe drought.

Additional work on these problems undertaken in 1939 and 1940 included the elucidation of soil and plant ecological relationships at Yudnapinna by means of a survey carried out by the Division of Soils. A reconnaissance visit was also made to the north-east pastoral country. Pot culture tests with pastoral soils indicated that their general level of fertility was low compared with Waite Institute soil. This was especially so with soils collected from Yudnapinna.

(2) *Murray Mallee: Tests of Pasture Plants at Pallamana.*

Observations have been continued on an area planted in 1937 and in subsequent seasons with a large number of native and introduced herbage species. Further plantings, mainly of dry-land grasses from the United States, were made in 1939. Some species, including crested wheat grass (*Agropyron cristatum*), blue grama grass (*Bouteloua gracilis*), and buffalo grass (*Buchloe dactyloides*) have also been grown at the Waite Institute. In their natural environment the latter two grasses receive the benefit of a limited, though assured, rainfall, combined with low evaporation, in spring and early summer. These conditions do not obtain in South Australia, and the severity of the spring and summer conditions no doubt accounts for the failure of many introduced plants at Pallamana.

A noteworthy feature has been the continued success and prominence of native saltbushes and bluebushes. Charting was carried out in 1940 to record the natural regeneration resulting from the seed produced by the original plants. Outstanding in its regeneration and spread over the area is the saltbush *Atriplex stipitatum,* while seedling plants of bladder saltbush (*A. vesicarium*), creeping saltbush (*A. semibaccatum*) and the bluebushes *Kochia brevifolia* and *K. Georgei* are present in considerable numbers over the area.

The adaptability of the native perennial saltbushes and bluebushes to the soil and climatic conditions of the Murray Mallee has been exemplified by their greater development and power of regeneration as compared with the other indigenous and introduced species present.

Except for the closely allied species *Rhagodia spinescens,* which was heavily grazed on each occasion, the saltbushes and bluebushes proved relatively unpalatable to sheep when other herbage was available, but this factor may be in part due to the unfamiliarity of sheep bred in settled districts with this type of forage.

These observations have indicated that lucerne, barrel medic, Wimmera rye-grass, and perennial veldt grass, together with creeping saltbush, are likely to prove of value in the provision of cultivated pasture on marginal lands and that their use in conjunction with cereals provides an important subject for practical investigation. A long-term experiment was commenced in 1939 to test these and related questions and an account of this work is given on page 27. The studies carried out with pasture plants also suggest that a number of the perennial saltbushes and bluebushes could be grown successfully and would regenerate naturally in the Murray Mallee.

(3) *Murray Mallee: Pasture Establishment.*

An experiment designed to supply information on the establishment, persistency and productivity of various combinations of leguminous and non-leguminous plants on a typical mallee soil at Pallamana was commenced in 1938. The plots were sown on fallow, with and without wheat as a cover crop, which was either cut during the season to simulate grazing or allowed to proceed to maturity, and with two levels of superphosphate, $\frac{3}{4}$ and $1\frac{1}{2}$ cwt. per acre. The species sown were lucerne, barrel medic, early subterranean clover, Wimmera rye-grass, evening primrose, perennial veldt grass, and a mixture of three saltbushes—creeping, slender-fruited and *Atriplex campanulatum.*

A satisfactory establishment of all species except evening primrose and saltbush resulted, and the presence of the cover crop did not bring about any reduction in plant numbers nor did the higher level of superphosphate result in any increase. A heavy infestation of capeweed in association with a very limited rainfall brought about a high mortality of the seedlings, so that the yields of the sown pasture species were low on all plots and showed no response to the higher fertilizer application nor to the cutting of the accompanying cereal during the season. The yield

of wheat was higher when cut only at the end of the seasonal growth, but showed no response to the additional ¾ cwt. of superphosphate.

Counts made in the following autumn of the number of surviving plants of the perennial species showed that a further heavy loss took place during the summer and also that the numbers of new seedlings arising from the annual species were very small also.

The presence of the cover crop in the previous year resulted in a greater reduction of the number of surviving plants of lucerne and perennial veldt grass than where no cover crop was present, while the cutting of the cover crop twice during the season has benefited the annual legumes, subterranean clover and barrel medic to some extent. The higher level of superphosphate was without effect on plant numbers.

(4) *Murray Mallee: Experiments on Drift Sand.*

Initial tests, carried out in 1937, showed that rye corn was capable of temporarily stabilizing an area of actively drifting sand on which other crop and herbage species failed completely while the drift was active.

Seedings were made in 1938 on rye stubble covering sand that had been seeded to rye in 1937. These included lucerne, barrel medic, early subterranean clover, perennial veldt grass, Wimmera rye-grass, evening primrose and Mediterranean grass, alone and in various combinations.

Satisfactory establishment occurred with all but two species; that of evening primrose and Mediterranean grass was low. Owing to the exceedingly dry conditions of the 1938 winter a heavy mortality of plants occurred, and at sampling in October only barrel medic and lucerne contributed materially to the yield.

Counts made in 1939 of the perennial species—lucerne and perennial veldt grass—revealed that in each case only about 1 per cent. of the plants present in 1938 had lived through the 1938–39 summer. Barrel medic had, however, seeded well in the first year, and a dense growth of this species occurred in 1939 on all plots in which it had been sown. The soil surface was sufficiently stable to permit the germination and establishment of evening primrose in large numbers, but plants of lucerne, subterranean clover, Wimmera rye-grass, and perennial veldt grass were few. The rainfall in 1940 was particularly low, resulting in poor yields of barrel medic, but evening primrose continued to spread. Successional changes are evident on some plots. Seedlings of spear grass have become established following evening primrose, which in turn was dependent on the earlier stabilization by rye.

Following an application of superphosphate at the rate of 1½ cwt. per acre to all plots in 1939, differential dressings of 0, ½, and 1 cwt. per acre were applied in 1940. Owing to the dry season and the residual effects of the dressing applied in 1939 there was no significant response to these applications.

Pyp grass (*Ehrharta villosa*) is another species capable of effecting the permanent stabilization of drifting sand and has proved effective in controlling a large area of drift near Murray Bridge. An attempt was made in 1938 to improve the productivity and fertility of this area by seedings of barrel medic and evening primrose, together with the application of varying quantities of superphosphate. The establishment and growth of both species were poor. There was some response to the application of superphosphate by naturally-occurring *Medicago minima* in the first season, but pyp grass did not respond in either season. It is presumed that the low level of fertility, particularly of nitrogen, has inhibited any response by pyp grass to phosphate and that the extensive root system of this plant utilizes the limited supplies of soil moisture very completely, thus rendering the establishment of other species almost impossible.

8. Pasture Establishment in Conjunction with Crop Rotation and Land Use, Pallamana.

The exhaustive cropping system of bare-fallow wheat has led to a decline in wheat yields and a widespread incidence of sand drift on the light-textured mallee soils of marginal areas in southern Australia. The problem is an urgent one, and its solution is bound up with an altered use of the land, involving in particular wider crop rotations and the establishment of pastures that are superior in productivity to the naturally-occurring ephemeral grasses and weeds induced by cropping for wheat.

To provide information concerning these questions a long-term experiment was commenced at Pallamana in 1939 on an area of approximately 7 acres, laid out into 64 plots of ·105 acre each. The design of the experiment provides for a series of eight rotations, each with wheat on fallow as the main crop, but accommodating one, two, and four cash crops in eight years, together with natural and seeded pastures; the latter are established under different conditions as shown in the following table:

Rotation	Year. 1	2	3	4	5	6	7	8
A	Wheat	N. Pasture	Oats	Fallow	Wheat	N. Pasture	Oats	Fallow
B	Wheat	N. Pasture	N. Pasture	Fallow	Wheat	N. Pasture	N. Pasture	Fallow
C	Wheat	N. Pasture	N. Pasture	N. Pasture	N. Pasture	N. Pasture	N. Pasture	Fallow
D	Wheat*	Pasture	Pasture	Pasture	Pasture	Pasture	Pasture	Fallow
E	Wheat	S. Pasture*	Pasture	Pasture	Pasture	Pasture	Pasture	Fallow
F	Wheat	N. Pasture	Oats*	Pasture	Pasture	Pasture	Pasture	Fallow
G	Wheat	Fallow	S. Pasture*	Pasture	Pasture	Pasture	Pasture	Fallow
H	Wheat	N. Pasture	N. Pasture	Fallow	Saltbush +barrel medic	Pasture	Pasture	Fallow

* Seeded pasture mixture established either with crop or alone as indicated.
N. Pasture = natural pasture. S. Pasture = seeded pasture.

Each course of the rotations A–H is sown in every year. Seedings of oats in rotations A and F, and pasture in rotations E and F are on summer-ploughed land.

The seeded pasture mixture employed in rotations D, E, F, and G was based on the results of previous trials with herbage plants at Pallamana and includes the species most likely to be successful under practical conditions of seeding and management. These are lucerne, barrel medic, Wimmera rye-grass, and perennial veldt grass. In rotation H, creeping saltbush and barrel medic are seeded on fallow and allowed to remain as pasture for three years before the land is fallowed again for wheat. This test is of particular interest, as large-scale experimental seedings of saltbush have not previously been conducted over a period of years.

The crop yields in the different rotations are recorded each season, and in addition, information of value will be gained concerning the establishment, persistence, and productivity of an improved pasture mixture seeded on fallow and on summer-ploughed land, with and without cover crops, under conditions widely differing according to the season. Soil samples are taken at monthly intervals from depths ranging to six feet on certain rotations. The moisture content of these samples is determined in the laboratory.

The experiment is necessarily of long-term duration, and it will be several years before data can be published; but in the meanwhile valuable knowledge of a preliminary character is being gained.

The conditions at Pallamana in 1939 and 1940 were particularly dry during the normal growing season, but relatively heavy rains were received in summer (*vide* page 54). The results obtained in these two seasons emphasize the necessity for a year's fallow before the seeding of any crop or pasture. Cover crops appear to favour a better establishment of all species seeded in the pasture mixture, but

subsequent competition for moisture later in the season may nullify this advantage unless the crop is grazed. Up to the present perennial species have proved outstanding in the sown pasture mixtures. Creeping saltbush appears particularly promising, followed by lucerne and perennial veldt grass. The latter, whilst establishing and persisting well, has so far produced disappointing yields. The two annual species, Wimmera rye-grass and barrel medic, were practical failures in 1939 and 1940.

4. WEEDS INVESTIGATIONS.

An investigation of two serious weeds of South Australia, the single-leaved cape tulip (*Homeria collina*) and two-leaved cape tulip (*H. miniata*) was commenced at the Waite Institute in 1940. Work on the former had previously been carried out by the Council for Scientific and Industrial Research.

In a pot culture experiment, the effects of modifying several environmental factors were determined. Aeration of the soil was increased by mixing fine coke with the surface soil, which in each case was one suited to the growth of that species. The moisture level was varied by allowing the soil to dry out until wilting occurred and then watering; there were two levels of nitrogen, and competition from a grass and from a legume were compared with no competition. Wimmera rye-grass was employed as an associate grass with each species of tulip. Legume competition was provided by subterranean clover in the case of *H. collina* and by barrel medic in the case of *H. miniata*. After harvest the corms, cormils, stems, leaves, and seeds were separated and their dry-weights determined.

With both species, and with each separated fraction, plant competition was the most important factor in causing a reduction in the growth of cape tulip. The grass and the legumes were equally effective in this respect. Periodic drying of the soil reduced the aerial growth of *H. collina*, while the addition of nitrogen greatly reduced corm production in this species. Where rye-grass was grown in association with *H. collina* on non-aerated soil, the combination of high moisture and low nitrogen produced a significantly greater weight of corms than any of the three remaining combinations of nitrogen and moisture levels. Under this treatment the grass was limited by the low nitrogen supply and was unable to utilize fully the available soil moisture. Decreased effectiveness of competition under these conditions was also indicated by greater seed production on the part of the tulip.

Increased soil aeration greatly reduced the aerial growth and corm production of *H. miniata*, except where the latter was subjected to competition from rye-grass. Periodic drying of non-aerated soil containing tulip grown alone produced a smaller decrease. The addition of nitrogen to tulip grown with rye-grass significantly reduced corm production.

In conjunction with the pot culture investigations, two field experiments were also commenced in 1940. In the northern parklands of Adelaide, which are badly infested with *H. miniata*, the effects of phosphate application, monthly mowing, cultivation, and various levels of nitrogen supplied as sulphate of ammonia are being investigated.

Cores of soil six inches in diameter were taken each month from four treatments, comprising all combinations of no nitrogen and heavy nitrogen, mown and not mown. The first samples were taken early in June, about six weeks after the sprouting of the corms, which at the time of sampling were very low in food reserves, these having been expended in leaf production. The weight of corms had not changed significantly at the next two harvests. Further depletion of reserves in the old corms was apparently compensated by the first stages in the formation of new corms.

The period from the end of July to early September—that is, the month immediately prior to flowering—produced a marked increase in weight of corms in plots that were not mown. Repeated mowing reduced the development of new corms, preventing any significant increase in this period; at each of the final three samplings the weight of corms taken from the mown plots was less than a quarter of that from plots not mown.

The application of sulphate of ammonia in large quantities reduced the weight of corms produced on plots that were not mown, but had no effect where the tulip was mown.

At Anama Station, near Clare, investigations that had been commenced by the Council for Scientific and Industrial Research were continued. An experiment was commenced in 1940 to determine the effect on *H. collina* of various combinations of manurial and cultural factors with spraying. Applications of sulphate of ammonia, lime and phosphate were tested in conjunction with chlorate sprays, different seeds mixtures, top-dressing with minor elements, and injection of the soil with kerosene. The treatments were applied in August, and dry spring conditions followed. Pasture cuts made at the end of the season did not reveal at that stage any differences in tulip growth due to treatment.

A study was made in 1940 of the vegetative characters of the more important weeds occurring in South Australia with a view to the ready identification of these plants at early-growth stages under field conditions.

5. BOTANICAL SERVICE.

The purely botanical work of the Institute concerns the accurate identification of plants, the maintenance and development of the Herbarium for reference purposes, and some attention to the Arboretum, which has an important demonstration value.

An advisory service is supplied to the Minister of Agriculture, also to the Minister of Afforestation, and to any other persons who wish to avail themselves of the service. Much plant identification is carried out on behalf of officers at the Waite Institute engaged on soil survey work or problems in agronomy.

The Herbarium now includes over 4,200 specimens, each of which has been named, mounted, and preserved from attack by insects.

Approximately 700 specimens were identified in 1939–40. Most of the enquiries have been received through the Department of Agriculture and the District Councils, but substantial numbers have also been sent by enquirers direct. Particular stress is laid on the early recognition of noxious weeds or plants likely to become noxious.

A representative collection of native and introduced pasture plants has been mounted in glass cases and displayed in the corridors of the laboratories for purposes of general information.

Exhibits of important weeds were prepared for the Royal Agricultural Show in 1939 and for the Conversazione of the Royal Society of South Australia, held at the Waite Institute in the same year.

The collection and growth of seeds from native and introduced plants capable of establishment on eroded areas have been continued.

Considerable public interest was shown during 1940 in the wormseed oil plant (*Chenopodium anthelminticum*). It is now established that this species grows spontaneously to a limited extent in South Australia. Seed has been collected and an experimental crop grown with summer irrigation at the Waite Institute. The species grew and yielded well under cultivation. The content of ascaridole has also received attention.

Plant Physiology

1. Growth Studies.

The increase in yield of crops and the improvement of the quality of plant products depend ultimately upon control of the growth and development of the individual plant. In the report for 1937–38 an account was given of investigations on the factors governing the amount and distribution of nitrogen in gramineous plants. In these investigations particular attention was paid to changes in the nitrogen content of the various parts during growth, to effects thereon of manurial treatment, and to the transfer of nitrogen from the leaves to the inflorescence. A similar study has now been made for a second important nutrient element, phosphorus. This has involved the development of techniques for estimating different groups of phosphorus compounds in the plant. An extensive set of data has been obtained concerning the distribution of phosphorus in the oat plant and the proportions of the different types of compound in which the element occurs in the leaves.

An examination has also been made of the methods of calculating the net assimilation rate, resulting in elimination of certain errors normally inherent in the calculation. The net assimilation rate correctly stated and calculated should afford a comparative measure of the efficiency of different plants in producing dry matter. It can be expressed either per gramme of dry matter in the leaves or per gramme of protein in the leaves. The latter basis has been found of considerable value in interpreting effects of the environment and nutrient supply on growth. The efficiency of the plant expressed in this way decreases as the nitrogen status of the plant increases. Thus it has been found that increasing the nitrogen supply to the plant decreases the net assimilation rate on a protein basis. On the contrary, increasing the phosphate supply over a certain range increases the rate; this range is that over which the increase in phosphate causes increased growth, with consequent decrease in nitrogen status. These results could possibly be accounted for if a luxury consumption of nitrogen occurred and if the excess nitrogen were converted into storage, rather than active, cytoplasmic protein.

2. Drought Resistance.

The growth studies described in the foregoing section, although of a fundamental character, have direct relations to practical problems; in fact, a great range of agronomic work calls for a knowledge of the developmental physiology of the plant, especially in relation to nutrient supply, and it is precisely this knowledge that these investigations have been designed to supply.

Certain extensions of the growth studies have, however, also been made into fields of more specific agricultural interest. One of these is drought resistance, a field into which it is hoped to make further excursions later. A comparative growth study has been made of barley and rye—two plants differing considerably in their reaction to drought. The results have permitted some steps to be taken in the physiological interpretation of this different reaction.

3. Nitrogen Metabolism.

Further work has been done on the relation between proteins and amino-acids in leaves. The nature of the relation could not be shown to be affected by the carbohydrate content of the tissue, although it appears to be influenced to a small degree by the nitrogen supply to the plant. The main determinant of the form of the relation, however, is the water content of the tissue, and it is possible that differences in drought resistance among plants partly depend on differences in the extent to which reduction in water content affects this relation and leads to protein break-down.

4. Studies on the Tobacco Plant.

Since 1935 studies on the growth of the tobacco plant have been carried out on behalf of the Council for Scientific and Industrial Research. These have aimed at obtaining fundamental knowledge of the plant which would be of value in understanding the cause of bad quality. Quality in tobacco is determined largely by the composition of the leaf at the time of picking, and it is generally believed that, among other factors, high contents of nitrogen and fibre and low contents of sugars and organic acids contribute to poorness of quality. The work has consisted of a study of the developmental physiology of the plant under various environmental conditions; this has in particular included a study of the factors operating during development that determine the chemical composition of the mature leaf. The results should provide a foundation for subsequent investigations of particular aspects of the quality problem.

The distribution of nitrogen within the plant during development has received special attention, since nitrogen content appears to be one of the most important determinants of quality. Protein break-down commences after the leaf is fully grown and by the time the technical stage of ripening has been reached a considerable amount of nitrogen has been lost from the leaf. That from the ripening lower leaves passes to leaves higher on the plant which are younger and still building up proteins: that from the upper leaves in an untopped plant passes to the inflorescence; in a topped plant it passes to the roots and stems, which continue to grow, mainly by increase in thickness. Proper ripening is dependent upon adequate removal of nitrogen from the leaves. It is suggested that, if environmental conditions are such as to inhibit late growth, i.e., in the upper leaves, the stems, and the roots, nitrogen will tend to remain in the leaves and ripening will be delayed.

A study has also been made of the changing content of organic acids and other compounds in the leaves during the growth of the plant. The changes in both nitrogen and organic-acid contents are such as to indicate that late picking should be advantageous to the quality of the tobacco.

The growth of the plant was studied in relation to the phosphate supply, since it is known that increasing phosphate supply up to an optimum increases the size of the mature plant and so decreases its nitrogen content; the response, however, was not as great as that found in cereals, owing to the restriction in capacity for growth resulting from topping and suckering. Increasing phosphate supply decreased the organic-acid and reducing-sugar contents and, to a slight extent, the nitrogen content of the ripe leaves. Ripening was also earlier. In fact, by varying phosphate supply between a high dressing and one that was moderately, but not markedly, deficient, the time of ripening could be varied by about a fortnight. It is clear that knowledge of the optimum phosphate requirement of a given crop is desirable; excess phosphate is disadvantageous since it decreases the organic-acid content of the leaves.

An investigation has been made of the effects of topping on the development of the plant and the composition of the leaves. Knowledge of these effects should be of interest since much Victorian tobacco is now grown untopped.

Experiments have been carried out on the relation of water supply to growth. Marked effects on the nitrogen and carbohydrate contents of the leaves were produced by drought, details of which will be given in the next report. The effects were such as to suggest that inadequate water supply may be an important factor causing poor quality in Australian tobacco.

On account of the reputed bad quality of tobacco grown in heavy soils, growth of tobacco was compared at the Waite Institute in a sample of heavy soil from Tamworth, New South Wales, known to produce poor tobacco, with that in a sample of sandy soil from McLaren Flat, South Australia, which is known to

produce tobacco of good quality. Despite the high nitrogen content of the former soil, under optimum conditions low nitrogen plants were obtained. With deficient water, however, the nitrogen content of the plants was very high and ripening was greatly delayed. Probably then the cause of bad quality in heavy soils is to be sought in a combination of soil and climatic factors, among which water supply may play an important part.

Plant Pathology

The Department of Plant Pathology is concerned with three types of work: research concerning plant diseases of particular moment in South Australia, the provision of advisory services to the Departments of Agriculture, and Woods and Forests, and teaching within the faculties of agricultural science and science of the University of Adelaide. A general review of the research problems under investigation is given below. The provision of an advisory service, both directly and indirectly through the Department of Agriculture, embracing as it does the diseases of a wide range of agricultural and horticultural plants, occupies a considerable amount of time, but the service is regarded as an important one. Not only does it represent a service to the general community, but it is also a means whereby the Waite Institute is kept in touch with problems confronting South Australian growers. Accumulated experience gained in this way has allowed workers at the Institute to obtain a sound view of the variety and relative importance of the many diseases affecting economic plants. This survey, although it reveals that there are many problems calling for research, also shows those most needing investigation. One further aspect of this advisory service developed during the period under review should be mentioned. This is connected with the decision of the Department of Agriculture to establish a potato seed certification scheme in South Australia.

An important element in healthy seed potatoes is freedom from virus disease. Although workers in the Commonwealth Council for Scientific and Industrial Research in recent years have done much work to elucidate the nature of the many virus diseases affecting potatoes, their diagnosis in the field still presents difficulties, and considerable assistance has been given to the Department of Agriculture in this direction.

Disease in plants may arise from a variety of causes. In some cases the main feature is the attack of parasitic fungi or bacteria. In others the cause is a virus, or it may lie primarily with a deficiency in certain food elements in the soil. These distinctions are not sharp, but they are useful here because investigations relating to the first group of diseases are covered in the section below. Investigations concerning virus disease and those due to deficiencies in certain minor elements of the soil, necessary for healthy plant growth, are dealt with in other sections of this report. The subjects under investigation in this section are best dealt with in terms of the crops or group of crops concerned.

1. Cereal Diseases.

Wheat is the most universally-grown crop plant in South Australia. The most important group of diseases, economically speaking, affect the underground portions of the plant. A considerable variety of fungi and other organisms, which have been referred to in earlier reports, fall for consideration in this matter though it is considered that certain ones among these, e.g. the fungus *Ophiobolus graminis,* are especially important. Most of the work on this group of diseases is being done with this organism, and the disease, known as "take-all", which it causes. Of

diseases affecting above-ground parts of the plant, rust is seasonal and fortunately not frequently important. The problem of effectively controlling rust and certain other diseases like flag smut is largely a matter of breeding resistant varieties, work on which is proceeding at the Institute and is referred to elsewhere in this report. Although it is the hope of plant breeders that bunt will eventually be controlled through the use of resistant varieties, seed treatment is still generally necessary and some work on the evaluation of the newer types of seed dressings, including organo-mercurial compounds, has been done.

(1) *Eye-spot Lodging of Wheat (Cercosporella herpotrichioides).*

This disease, which has secured prominent notice in Europe and in the north-west States of the United States of America, was recorded for the first time as present in South Australia (Reprint No. 284). The fungus attacks the base of the plant and promotes a type of lodging which may easily be confused with that caused by bad weather. If we take into account the results of observations made abroad, it appears likely that the local climate is, generally speaking, unfavourable to the extensive development of this disease, so that it may have been present for some time without attracting attention. Certainly there are no grounds for suspecting a recent introduction.

(2) *"Take-all" of Wheat.*

Work on this problem, the general nature of which has been described in previous reports, has been continued. In the field a long-term experiment is being conducted in co-operation with the Council for Scientific and Industrial Research and the Department of Agriculture at Brooker on the West Coast (Eyre's Peninsula) in a field known to be badly affected by "take-all" at the start of the experiment. This experiment is designed to test the influence of rotational, managerial, and manurial systems on the survival of the disease. Similar proposals for a second experimental area in the Murray Mallee district have had to be modified on account of soil drift.

At the Waite Institute observations were made annually over a period of five years on an area which in 1935 had "take-all" quite badly and was cropped continuously. These observations showed that in this soil "take-all" practically "died out" after the first four years, despite the continuous cropping. They also showed that superphosphate dressings are important in reducing the percentage disease present and that it has a cumulative effect. The effects of tilth, dressings of sulphate of ammonia, and varietal resistance were also studied. Tilth had a variable effect, sulphate of ammonia had no effect, while there were slight, but in some cases significant, differences in varietal response. The effects of phosphate dressings and rotational cropping on this same ground on yield in 1939 are referred to more fully in the section of this report on Field Crops and Pastures. Other work with pot cultures under controlled conditions in the glasshouse and studies on the physiology of the fungus in pure culture were continued.

(3) *Evaluation of Cereal Seed Dressings.*

At the present time copper carbonate is the standard material used for dressing wheat to control bunt. Under local conditions this material usually gives very effective control, but the possibility of even greater efficiency and of other advantages exists. With these objectives a series of field and laboratory tests was started in 1937 and has been in progress ever since. The materials used have had either copper, organo-mercurial, or non-metallic organic compounds as their active constituents and have been supplied by Imperial Chemical Industries of Australia and New Zealand Limited, who are co-operating in the work.

Besides evaluating these materials in respect to their effects on germination, growth as measured by yield, and efficacy in bunt control, some attention has been given to their possible value in controlling certain soil-borne fungal diseases. Work has also been done on barley, in which the control of leaf stripe (*Helminthosporium gramineum*) and covered smut (*Ustilago hordei*) are being studied. For these diseases copper carbonate has proved relatively ineffective.

2. Horticultural Plant Diseases.

(1) *Rind Blemish in Oranges.*

Further work on this subject, which was started in 1938 and referred to in the last report, has been carried on in co-operation with the Council for Scientific and Industrial Research and the Department of Agriculture. Various fungi, including species of *Colletotrichum, Septoria,* and *Alternaria,* are commonly present in the brown, discoloured areas found in stored oranges, and the question of the part they play in their causation comes up for consideration. The main line of approach so far taken has been to discover when infection takes place and its extent. This work has confirmed the extensive occurrence of so-called "latent infection" of apparently sound oranges and has shown that oranges may be infected quite early in their development on the tree. The degree of infection varies greatly in different districts and in different seasons. Certain spraying schedules greatly reduce the degree of infection.

Last season the Department of Agriculture undertook an extensive series of storage experiments with fruit subjected to various heat treatments prior to storage and with oranges from sprayed trees. Parallel samples were taken to ascertain the effects of these treatments on latent infection with a view to determining whether a correlation existed between the extent of storage spot development and reduction in latent infection. Some evidence of this has been obtained.

(2) *Grapevine Disease.*

A disease, the symptoms of which were briefly described in the last report and were considered to resemble the European disease court noué, has been studied further. Pursuing the idea that the disease may be due to infection with a virus, attempts have been made to transmit the disease by grafting, but these have been unsuccessful, the diseased scion wood used failing to form a union. However, some cuttings from lightly-affected vines have been rooted successfully and further work to test the transmissibility of the disease should be possible. The possibility that the disease is due to an inadequacy of certain minor elements has been tested, both in the field—using infection methods and spraying—and in sand cultures in the glasshouse, but so far without securing positive evidence.

(3) *Tomato Diseases.*

The bacterial wilt of tomatoes referred to in the last report as being new for South Australia has been under observation in the field and the subject of experimental work. Studies on its physiological characteristics reveal the similarity of the local causal organism with *Aplanobacter michiganense* E.F.S., but the symptoms observed in infected plants locally differ from those described elsewhere, in that cankering has not been observed and the xylem rather than the phloem region is the area invaded.

A plant-breeding programme designed to produce types of tomatoes resistant to *Fusarium* root rot and leaf mould (*Cladosporium fulvum*) and otherwise suitable for the local glasshouse growing industry is in progress. Some promising

types are now in the F_2 generation. Work is also in hand along the same lines with a view to securing varieties suited for outdoor growing and more tolerant to infection with spotted wilt.

3. Forest Tree Diseases.

Fortunately the Monterey Pine (*Pinus radiata*), which is used extensively for plantation purposes, suffers very little from attack by parasitic disease in South Australia. *Diplodia pinea* is sometimes found associated with "dead topping" in the forest. Some successful inoculation experiments have been done with young trees in open ground, but the results, coupled with observations made in the field, suggest that the capacity of this fungus for parasitism is quite limited.

4. Miscellaneous.

The possibility of producing ergot in cereal rye by artifiicial inoculation was tried out at three centres in 1940. The spring season was very dry and the yield of ergot was low. The growing season in South Australia normally is comparatively short, and since mounting temperatures and rapidly drying weather characterize the spring, the environment, judging from European observations, is unlikely to be as suitable for ergot production as many other parts of Australia.

Entomology

The work of the Department of Entomology during 1939 and 1940 has developed on the lines reviewed in the previous report. During 1940 particular attention has been directed to insect infestation of stored wheat, prepared cereal products, and stored foodstuffs in general.

1. Locust and Grasshopper Investigations.

The investigation on the ecology of the Australian locust (*Chortoicetes terminifera* Walk.) in South Australia, which was begun in 1935, has now been completed (Reprint No. 288). It has been shown that this species occurs as a solitary grasshopper over the greater part of the State, but the combination of favourable conditions which allow it to increase to serious plague proportions rarely occur in South Australia, and plagues have occurred in 1845 and three times since then. The "outbreak areas" for this species, where swarms originate, are situated in the semi-arid country lying north of the 10-inch annual rainfall line. The development of swarms in these areas is brought about by a sequence of years in which the rainfall favours the multiplication of the insect. In the agricultural districts the cold, wet winters prevent the insect increasing in numbers, and swarms do not normally develop.

The geographical boundaries of the outbreak area are determined largely by rainfall and temperature. The whole of this area is not suitable for the insect; local situations, due to particular topography, soil type, and vegetation, favour the development of swarms of the locust. The knowledge which has been established on these matters and the character of the seasons which favour the development of locust swarms should enable us to be forewarned of future plagues of this species in South Australia before the swarms extend southwards into the agricultural districts. This will enable control measures to be organised in these areas.

Local swarms of this locust invaded irrigated areas around Berri early in December, 1939. A field survey was carried out which showed that they had originated in grassy flats on the flood plains of the River Murray, situated east of Berri. These flood plains will provide restricted breeding areas in certain years.

Investigations on the small plague grasshopper (*Austroicetes cruciata* Sauss.) have been continued. The species was abundant in 1939 for the fourth successive year, but the outbreak rapidly declined in the spring of 1940 owing to the prolonged period of drought. Large numbers of eggs had been laid in the early summer of 1939, and hatchings were heavy throughout the grasshopper belt in September, 1940. The majority of the hoppers died before reaching the egg-laying stage, owing to the absence of green herbage; many of the hoppers which attained the adult stage did not lay eggs. Hoppers congregated in local situations, such as depressions, where green herbage was present. They were heavily preyed on by birds which were attracted to these situations owing to the shortage of food over the countryside.

The field survey work on this species was extended into New South Wales in 1939, and a tour of the grasshopper belt in that State was made in November. Widespread drought also occurred in these areas and resulted in a marked reduction of the grasshopper population. These observations make a useful contribution to our knowledge of the influence of weather factors on grasshopper abundance. The favourableness of future seasons may largely determine when the grasshopper population will again attain plague numbers.

Laboratory experiments have been carried out to determine why the eggs of the small plague grasshopper are able to remain viable in the soil from the time of being laid (about November) to the period of hatching in the following spring (about September). The eggs go into an enforced "diapause." This phenomenon is related to the temperature and rainfall in the bioclimatic belt in which the species persists: it is a safeguard to enable the insect to carry over the dry summer months and the cold winter months. It has been found that eggs in a state of diapause will not develop normally when incubated in favourable conditions of temperature (16°C. to 32°C.) and moisture. The retarding influence of the "diapause factors" on growth of the embryo in the egg gradually decreases during the summer months and a slow growth of the embryo takes place up to about the end of April. The retarding influence is finally eliminated about early June, at which time the embryo has completed the blastokinesis stage of development. When the eggs have attained this stage they will develop and hatch normally when placed under favourable conditions of moisture and temperature. Grasshopper eggs have beeen collected in the field throughout the year and incubated under these conditions of temperature and moisture: of the eggs collected before 29th May, none completed its development and hatched when maintained under these conditions; with eggs collected soon after 29th May, 66 per cent. developed and hatched, and by 19th June all the eggs collected developed and hatched.

Experimental work has shown that eggs in diapause strongly resist loss of water compared with eggs which have not attained this stage of development or have completed the diapause stage. The knowledge which has been established by these experiments will enable us to understand more clearly why this species is able to multiply into plague numbers in certain areas.

Field observations have shown that areas in the grasshopper belt in which the natural flora has been destroyed, in association with particular types of soil, become favourable breeding grounds for the species. This ecological aspect of the problem may lead to the development of fundamental and far-reaching natural means of control in marginal areas by regeneration of the vegetation cover.

2. Insects of Agricultural and Horticultural Crops.

(1) *The Oncopera Grass Grub* (*Oncopera fasciculata* Walk.).

The larvae of this moth are a pest of pastures in restricted districts around Mt. Gambier. They live in tunnels up to six inches deep in the soil and cause bare patches in pastures by eating off the young grasses and clovers. The damage shows up in autumn and increases throughout the winter. The larvae and pupae, moving actively in the burrows, may be found about September; the moths emerge by early October. The flight of the moths lasts less than an hour and egg-laying occurs shortly afterwards. Damage to the pastures does not become evident until about the following May. Cultivation of affected patches in the pasture when first observed, or spraying the areas with lead arsenate, has given satisfactory results.

(2) *The Philobota Pasture Moth* (*Philobota productella* Walk.).

The larvae of this moth occur in pastures in the better rainfall areas of the State; they eat young grasses and clovers, producing bare patches in the pasture, and are troublesome in lawns. The larvae live in vertical tunnels in the soil; these may be up to three inches in depth and are lined with strands of silk. The species may occur together with the *Oncopera* grass grub. The moths emerge during November: they fly about at night and lay their eggs in the pastures, taking shelter in grass during the daytime. The larvae hide in their tunnels during the day and feed at night. The damage in the pasture due to the feeding of the larvae begins to show up about June. Although the species appears to be widely distributed in the better rainfall areas of the State, it has been recorded as a pest only in a few restricted situations. Spraying the affected areas with lead arsenate has given satisfactory control.

(3) *Grapevine Webbing Mite* (*Tenuipalpus californicus* Banks).

Particular attention has been given to the occurrence of the webbing mite observed on grapevines in irrigated settlements on the River Murray during 1940.

The mites produce a dense, tangled webbing on the lower surface of vine leaves, particularly the Doradillo variety, although other varieties, including sultanas, are also affected. The mite infests the grape bunches and causes considerable damage in some instances. It appears to spend the winter in cracks and crevices of the bark of the woody portions of the vines and at the base of buds and short spurs. Damage by the mites to spurs has been observed.

(4) *The Gladiolus Thrips* (*Taeniothrips simplex* Morison).

Many complaints have been received from growers of gladioli who are disappointed by the inferior blooms they obtain due to the damage caused by the gladiolus thrips. Precautions can be taken to safeguard against this. The insects overwinter in the corms in the field or in storage; they appear on the young plants in spring and form colonies in the sheathed leaf bases as the plant grows. The corms should be placed in paper bags containing napthalene, for about three weeks, at the time of storing (1 oz. napthalene to 100 corms); care should be taken to ensure that the bulbs are thoroughly dry in the store. A foliage bait spray, as used by investigators in the United States of America, when applied to the growing plants once or twice a week during the growing season, gives satisfactory control of the insect. The spray consists of ½ lb. brown sugar, 2 oz. tartar emetic, and 3 gall. water.

(5) *The White Springtail* (*Onychiurus fimetarius* Lin.).

This cosmopolitan springtail frequently occurs in large numbers in damp soils rich in humus. It is a small, whitish insect about 1/25th inch long and is often associated with millipedes, which live in similar soils. Both pests may seriously damage seedlings. Treatment of the soil with a soil fumigant such as carbon bisulphide has given effective control. The fumigants are harmful to plants, and it may be necessary to wait a few weeks before replanting treated areas.

3. Insects Affecting Stored Foodstuffs.

In accordance with the decision of a conference of representatives of the millers', bakers', grocers', and storekeepers' organizations in South Australia, called by the Minister of Agriculture (Hon. A. P. Blesing, M.L.C.) in April, 1940, a preliminary survey has been made of the position in this State regarding wastage caused by the insect enemies of stored foodstuffs. The survey was carried out in co-operation with the Department of Agriculture and the trade organizations concerned.

An inspection of representative grocery stores and bakeries in the metropolitan area shows that, although insects cause damage to foodstuffs in some instances, the trouble is not extensive owing to the fact that stocks are turned over quickly. It will become more important should it be necessary for the trade to hold stocks for protracted periods.

Prepared cereals and dried fruits packed in paper containers may occasionally be found infested with larvae of the Mediterranean flour moth (*Ephestia kuehniella*) and the dried fruit moth (*Plodia interpunctella*). The larvae of these insects also occur in storage bins used for flour, bran, and pollard. They foul the infested material by producing the characteristic webbing. Examples were found of imported dates infested with the saw-toothed grain beetle (*Oryzaephilus surinamensis*).

The retail grocer largely avoids loss due to insect damage by making short-term purchases of stocks. Storage conditions, with the object of protecting stocks from insects laying their eggs on the materials, vary from place to place. If it becomes necessary to store goods for protracted periods particular attention should be given to the packing of prepared cereals and other foodstuffs and to their protection while stored so as to prevent the insects laying eggs in the materials.

The trades concerned are eager to take the necessary practical precautions, and there is a general desire for information about the common insects associated with stored foodstuffs. A pamphlet containing this information is being prepared.

An inspection was made of fifteen flour mills in the metropolitan area and in certain country towns. The Mediterranean flour moth is the chief insect problem. The larvae of this moth produce characteristic webbing in the materials they infest. This webbing impedes the movement of flour through the chutes and other parts of infested milling machinery. The larvae may wander into crevices in the floors, walls, and ceilings of the building, where they pupate.

A method widely employed to control this pest consists of introducing hydrogen cyanide vapour into the chutes, conveyors, and other parts of the milling machinery at suitable intervals; nicotine vapour is also used.

The Tribolium flour beetles (*Tribolium castaneum* Hbst. and *T. confusum* Duv.) commonly occur in mills; they do not appear to be directly harmful in the mill, but it is important that the insects should not have access to the flour: if the flour is contaminated with their eggs, infestation will develop in the material when it is placed in storage.

It is evident that cleanliness throughout the mill is essential if insect infestation is to be kept under control. Mills which have built up a trade in export flour are generally efficient in these matters; with the modern milling plant the deposition of flour dust through the machinery and its escape into the mill are largely controlled. The resulting cleanliness is an important factor in reducing insect infestation.

Fumigation of the parts of the milling machinery liable to harbour larvae of the Mediterranean flour moth, Tribolium beetles, and associated insects should be carried out weekly. The whole building should be fumigated at least once a year. In older mills attention to cleanliness is especially important, since there are more opportunities for the insects to find suitable places in which to live; more frequent fumigation may be necessary in these cases. Where flour is to be held in store for protracted periods great care must be taken to ensure that it does not become contaminated with the eggs of flour-inhabiting insects. Considerable wastage may occur in this way owing to subsequent insect infestation.

4. Insect Enemies of Stored Wheat.

Owing to war conditions resulting in the restriction of shipping space for the export of wheat, it has been necessary to store large quantities of bagged wheat in depot stacks for indefinite periods. An investigation is in progress relating to the infestation of stored wheat by weevils and associated insects. The work is being carried out in close co-operation with the State Superintendent of the Australian Wheat Board and the Division of Economic Entomology of the Council for Scientific and Industrial Research.

A survey has been made of the depot wheat stacks and storage sites at various centres throughout the State in relation to weevil infestation. Information has been accumulated about the insects attacking stored wheat in this State, and recommendations made for precautionary measures which should be taken to reduce their spread and multiplication. This information will shortly be published.

Observations are being made at suitable intervals on the changes taking place in the moisture content of bagged wheat and the humidity, temperature, and carbon dioxide content of the air in wheat stacks in relation to weevil infestation.

5. Studies on Ecology of Insects.

In addition to the general work of the Department, experimental work in the laboratory and systematic observations in the field have been continued relating to the influence of changes in the environment on the multiplication and geographical distribution of particular insects. These studies are made on certain species of grasshoppers, thrips, and springtails.

Soils and Agricultural Chemistry

1. WINTER SCHOOL IN SOIL SCIENCE.

During the period August 14–23, 1939, a highly successful Winter School in Soil Science was held at the Waite Institute under the auspices of the University and of the Council for Scientific and Industrial Research. The School was attended by representatives of the Universities, Departments of Lands, Irrigation, Agriculture, and Forestry, and by officers of the C.S.I.R. and the D.S.I.R. of New

Zealand. All the States of Australia were represented. Lectures and demonstrations were held in the following subjects:

1. The classification of soils.
2. The physical composition of the soil.
3. Soil colour.
4. The significance and measurements of soil structure.
5. Methods of soil surveying.
6. Water relations of the soil.
7. The infiltration rate of water in soils.
8. *Rhizobium*—its soil and host plant relationships.
9. The importance of trace elements for plant growth.
10. The polarographic method of analysis.
11. Spectrochemical analysis of soils and biological materials.
12. Methods for the determination of soil carbon.
13. Soil acidity and lime requirement.
14. Methods for the determination of soil reaction and soluble salts.

A full-day excursion was arranged for the inspection of representative soil profiles in the hills, in the Murray Mallee and on the Murray Swamps.

2. SOIL SURVEYS.

The headquarters of the Soils Division of the Council for Scientific and Industrial Research are at the Waite Institute. The interests of the Division are Commonwealth-wide, and work has been done in past years in all States of Australia. The main objectives have been, first, the systematic soil surveying of selected areas involving classification, mapping and study of soils, particularly in relation to their agricultural use, and second, the study of fundamental aspects of pedology and the zonal soil groups, both in the laboratory and the field.

The field work in 1939–40 has undergone certain changes from earlier operations. The trend has been towards less detailed surveys on a larger scale with more emphasis on the present and potential use of the land. Previously the surveys were mainly directed towards mapping areas of intensive settlement under irrigation with small holdings of high productivity and value. This necessitated close work, especially as these soils are very variable for irrigation purposes and frequently in need of reclamation. The survey of Red Cliffs (Vic.) in 1939 and Waikerie (S.A.) in 1940, together with some small areas in both States, brings to completion the mapping of the chain of irrigated horticultural settlements in the Murray system in New South Wales, Victoria, and South Australia. The study of these mallee and river flat soils has given a clear picture of the value of various soil types for irrigation, enabling a reasonable estimate of potentialities of new areas to be made.

Soil surveys vary in their nature according to the detail and information required for the proper use of the land. The present land use was covered in the survey of part of the Lower South-East district of South Australia in 1940, and is to be mapped in two other surveys during 1941. In the Wakool District in south-western New South Wales the development under irrigation and the comparative rating of the main soil types for pasture production are being studied. In the mid-north of South Australia the soil survey of County Victoria involves also an examination of the erosion position and the present and proper use of the land for soil conservation purposes. In these ways the soil survey is widening its scope, and on the fundamental basis of the soil map is building a plan for sound land use. The association of agronomists and skilled workers in other fields, such as forestry, engineering, and animal nutrition, is really essential for a complete study.

During the past two years more attention has been paid to ecological studies. Three such projects were completed. As a contribution towards the proper understanding of the vegetation and soils for the erosion and regeneration experiments of the Agronomy Department at the Waite Institute, a full field study was made of 25 square miles in a selected portion of Yudnapinna Station in the north-west of South Australia. The examinations regarding soils, erosion, and vegetation associations were later extended generally over the whole property in an exploratory manner. The soil survey of the South-East district of South Australia included wide mapping of the ecological relationships. In 1940 a reconnaissance survey was carried out of about 1,000 square miles on Kangaroo Island, embracing largely the natural scrub country which, in the light of recent experiments, is expected to be developed in the future. The survey, by defining the broad grouping of soils and vegetation, affords a guide for development and experiment.

Work was continued throughout most of 1939–40 on the survey of the Cobram-Numurkah district in north-central Victoria. A total of 330 square miles has now been completed. The area is being reticulated with channels for irrigation from the Murray River, a small part being already supplied. As the available water permits a maximum of 25 per cent. of each holding to be watered fully, it is important to have a clear view of the irrigability and estimated productive capacity of the soil types. The survey is already being used for advisory purposes and by the engineers in planning channel construction in localities with permeable soils.

The Cressy-Longford district in north-central Tasmania was surveyed in 1940. Some of the soils give poor results with pasture, and the examination was designed to study the occurrence and distribution of these problem soils and their relation to other local soils. Observations on the soils have been carried on for some years, and are still being studied in pot experiments at the Waite Institute. The field work placed the experimental work on a better footing, and opened the way for advice to be given from the results of the investigations.

The survey of Wakool Irrigation Area of 800 square miles in New South Wales was begun in 1940 and is proceeding. The field work embraces the mapping of the soils and collection of information on their productive capacity under irrigation, their salinity and irrigability. There is considerable room for improvement in the use of water to the best advantage.

The survey of irrigation areas in the Murray Valley has been going on since 1927. The study of the soils on the Red Cliffs settlement in Victoria was completed in 1939. The last major area to be mapped was Waikerie in South Australia. This settlement covers about 5,000 acres, and by comparison with other centres has a very high proportion of light soils, which have given rise to certain irrigation problems. There is also a deficiency of zinc, producing the condition known as "little leaf".

The next step is to deal with virgin land fronting the river as potentially suitable for settlement. In 1940 a request was made by the South Australian Government for a survey of the land within the Murray Valley in South Australia which could be irrigated on a low pumping lift, and available for future development. It was agreed to undertake a reconnaissance survey to this end, and some progress has been made. By special request a unit of 25 square miles of virgin country, north of Renmark, adjacent to the river, was examined in this connection. Work will continue in 1941 on new areas on both high and low pumping lifts to determine their suitability for settlement under irrigation.

A considerable volume of work was entailed in Divisional Reports to the State Governments in Victoria and South Australia, to other Divisions of the C.S.I.R., and in collaboration with other sections of the Waite Institute. A long report was submitted to the Woods and Forests Department on the relationship of soils and pine tree growth in the South-East district of South Australia. The ecological

investigations during the soil survey made it possible to determine the value of soil types so that the contemplated expansion of softwood forests was placed on a surer basis. The soil survey has been consistently used in the programme of forest extension. Following is a summary of field work completed in 1939–40:

South Australia:

South-East district, 350 square miles. Total now complete, 550 square miles.
Kangaroo Island, reconnaissance 1,000 square miles.
Yudnapinna Station, 25 square miles with additional reconnaissance.
Woolpoolool and Merreti Swamps, Renmark, 25 square miles.
Waikerie Irrigation Settlement, 5,000 acres.
Miscellaneous Irrigation Areas in South Australia and Victoria, 2,000 acres.

Victoria:

Cobram District, 200 square miles. Total now complete, 330 square miles.
Red Cliffs Irrigation Area, 2,000 acres. Completed area, 12,000 acres.

New South Wales:

Wakool district, 200 square miles. Survey continuing.

Tasmania:

Cressy-Longford district, 100 square miles.

Experience has shown the very great assistance afforded by aerial photographs in mapping soil and other land features. Accuracy and speed of surveying are improved considerably. A system of mapping direct on to the photographs has been worked out, and is being used successfully on two surveys now proceeding. Photographs were made on behalf of the Division of 800 square miles in the Wakool district, N.S.W., and of portion of the Yudnapinna Station, S.A. A set was available from an earlier flight for part of the Cressy district surveyed in Tasmania. A policy of photographing all areas to be surveyed in any detail has been adopted wherever possible.

3. GENERAL SOIL INVESTIGATIONS.

A development overseas of recent years has been a greater appreciation of the importance of the composition and structure of the minerals present in clays and in the colloid fractions of soils. It has not been possible so far to set up at the Waite Institute an X-ray diffraction unit, but valuable assistance in this respect has been received from colleagues at the University of California and the University of Western Australia. Other methods of identifying these mineral constituents have been studied, particularly dehydrating procedures.

The colloids separated from a series of Australian soils developed on granitic and basaltic parent materials have been examined in this way, and the clay and accessory minerals present have been identified. It was found that granitic materials had weathered to minerals of the kaolin type under a wide range of conditions, whereas in the case of the basaltic soils the type of mineral found reflected the soil moisture and drainage conditions operative during soil development. Kaolinitic types were observed under adequate moisture conditions with free drainage, whereas under drier conditions or under conditions of impeded drainage montmorillonitic types were more characteristic.

In the course of field work in Tasmania a group of soil types has been observed in the Cressy district on which pasture establishment has been poor, despite an apparently adequate supply of total phosphate (0·12 per cent. P_2O_5). The soil, in addition, has shown a marked lack of response to phosphate fertilization.

The soil is characterized in its colloid fraction by a clay mineral of the kaolinitic type and a relatively high content of iron minerals.

Pot experiments have been carried out on this soil, and the results for 1940 are encouraging. While the response to superphosphate alone has been negligible, the treatment of the soil with alkaline materials alone added in the form of lime, magnesia, calcium carbonate or limestone, or dolomite sufficient to raise the pH of the surface soil from its normal reaction of pH 6·1 to round about the neutral point, has given excellent results for subterranean clover. Where superphosphate also has been added, responses have been even more marked. However, where alkaline materials were added in excessive amounts and the reaction of soil raised appreciably above neutrality, the yields declined, owing no doubt to the creation of an environment too alkaline for the normal development of the subterranean clover.

The results for two series of treatments, including the use of magnesia and slaked lime, are given in the following table:

Yield of Subterranean Clover on Cressy Soil due to Various Treatments.

Treatments			Final pH of the soil.	Yield.	
Alkaline material.		Super.			
Form.	cwt. per ac.	cwt. per ac.		gm. per pot.	cwt. per ac.
—	—	–	5·8	3·22 ± 0·26	14·0
—	—	3	5·8	4·14 ± 0·30	18·1
MgO	9	–	7·7	17·30 ± 0·30	75·6
CaO*	22	–	7·6	17·34 ± 1·02	75·7
CaO*	22	3	7·1	22·77 ± 0·29	99·5
CaO†	16	3	6·9	22·88 ± 0·70	100·0
MgO	5	3	7·2	26·17 ± 0·72	114·3
MgO	9	3	7·5	23·17 ± 1·45	101·2
MgO	22	3	8·6	19·24 ± 0·68	84·0
MgO	87	3	9·4	4·41 ± 4·41	19·3

* Old slaked lime. † Fresh slaked lime.

4. IMPROVEMENTS IN LABORATORY TECHNIQUE.

Owing to the importance of mineral deficiencies in Australian soils, methods for the determination of traces of the so-called minor elements are constantly under review. Both the spectrograph and polarograph are in use, as well as the more purely chemical methods of analysis. In the case of the spectrograph where only minute quantities of soils, soil extracts, plant materials, and plant ashes are concerned, the technique of sampling and sub-sampling plays an important part, and some attention has been given to this problem. For example, the final concentration of soil extracts is carried out on the graphite electrode itself.

Experience over the past three or four years has shown that the polarograph can be used for reliably estimating micro-quantities of zinc, and the more recent improvements in technique have been in the direction of the simplification of the procedures without sacrifice of accuracy. A mixed solution of ammonium chloride and potassium thiocyanate has proved to be a satisfactory basal solution specifically for use in zinc estimations. In the study of the partition of zinc between a chloroform solution of dithizone and aqueous ammonium citrate buffers at different pH values, it was found that a high pH (9·5–10·0) permits the extraction of zinc from solutions of plant digestions, even when these contain suspended silica.

As little as 3 micrograms of zinc in a plant can now be readily estimated with an accuracy of ± 2 per cent.

The mechanical analysis of soils has been subject to further refinements, in particular with reference to improvement in the technique of sieving and the

securing of greater detail in the sand fractions. This greater subdivision is mainly justified when the data so obtained can be reinterpreted to give the distribution curve of the particle sizes in the non-colloid fraction of the soil. The rapid hydrometer methods now regularly used for the mechanical analysis of soils in engineering practice and for routine work are also under review.

In view of the importance of phosphate fixation by certain soils which have been encountered during the course of soil surveys or in the course of field experiments, methods are being developed for estimating the phosphate-fixing power or, alternatively, the anion exchange capacity, of these soils.

Methods for the determination of phosphorus and copper in plant materials have also been reviewed.

5. MINERAL DEFICIENCIES.

Investigations of mineral deficiencies have been concerned mainly with those relating to the essential nature of trace elements for plant growth, to the establishment of the symptoms of such deficiencies and to the practical solution of crop production and pasture establishment in those areas which are now known to be affected. Two important areas have been recognized carrying characteristic soils —the coastal district of the South-East of the State, with its characteristic calcareous sandy soil akin to the Currie calcareous sand first described on King Island in Tasmania, and the ironstone country of Kangaroo Island. There is evidence that many of the light soils carrying heath and sclerophyll scrub in many parts of the State are affected in some measure, as well as occasionally those which carry mallee. The most important of these deficiencies appears to be copper, with zinc as important in some cases also. Boron deficiencies have also been proved to occur, while deficiencies in manganese have been known for some considerable time. In the experiments in the Robe district the investigations have been carried out in collaboration with the Animal Nutrition Laboratory.

1. Water Cultures.

In addition to the ten major elements it is now recognized that at least five other elements (boron, manganese, copper, zinc, and molybdenum) are necessary for normal plant growth, and the objects of the present investigations include the observation and recognition of the most characteristic symptoms of these deficiencies in different plants and the determination of the optimum amounts of the various elements for normal growth. This is being done by the growth of plants in nutrient solutions prepared from highly purified reagents and with distilled water of special quality.

In this way copper deficiency symptoms have been reproduced in wheat, oats, rye, peas, Wimmera rye-grass, *Phalaris*, flax, tomato, subterranean clover, and lucerne. Controls grown in the presence of optimum concentrations of copper make normal healthy growth and complete their life cycle. Oats and peas were investigated in considerably greater detail. The growth of oats at different copper concentrations is shown in the accompanying photograph. Symptoms of copper deficiency appeared in all plants growing in solutions containing 0·01 mg. of copper or less per litre, and no ears were produced by any of these plants. The first recognizable symptoms of copper deficiency appeared in the copper-free cultures about five to six weeks after setting the seed to germinate. At a level of 0·02 mg. of copper per litre the only evidence of copper deficiency was the decreased grain yield compared with that of plants receiving more copper.

By controlling the amount of manganese in another series of water cultures, "marsh spot" of peas was reproduced, thus confirming what had long been sus-

1 2 3 4 5 6 7 8 9 10 11 12

ALGERIAN OATS GROWN IN NUTRIENT SOLUTIONS WITH VARYING AMOUNTS OF COPPER.

Jar No.		Jar No.	
1	Copper, nil.	7	Copper, 0·10 mg. per litre.
2	„ 0·003 mg. per litre.	8	„ 0·25 „ „ „
3	„ 0·006 „ „ „	9	„ 0·50 „ „ „
4	„ 0·010 „ „ „	10	„ 1·00 „ „ „
5	„ 0·020 „ „ „	11	„ 2·00 „ „ „
6	„ 0·050 „ „ „	12	„ 3·00 „ „ „

The scale is shown by the metre rule in the centre of the photograph.

pected—that this disease is associated with a restricted intake of manganese by the plant.

In the case of zinc, symptoms of deficiency in oats occurred with concentrations of up to 0·02 mg. of zinc per litre. The growth increased progressively as the amount of zinc was increased from zero to this amount.

The essential nature of molybdenum for the growth of plants was confirmed in several series of water cultures. Characteristic leaf symptoms of molybdenum deficiency were recognized in oats at the heading stage. The yield of grain was only one-third that of plants receiving adequate traces of this element, and the grain consisted entirely of empty husks. So far no naturally-occurring plant diseases have been attributed to a deficiency of molybdenum.

Although cobalt is of importance in animal nutrition, no evidence has been obtained in any of our experiments that cobalt is of importance in plant nutrition. Oats produced normal healthy growth, both in its presence and absence from the culture solutions.

The amounts of copper found in whole oat plants growing on normal soils vary over a relatively narrow range, and average 2·5 mg. per kg. The manganese content is more variable. The zinc content is being determined in the same range of samples. The content of these elements in a variety of plants is now under investigation.

2. Pot Experiments.

Pot experiments have been conducted on a variety of soils suspected of deficiencies of various types in order to ascertain the nature of the deficiency and the probable response of crops in the field. In some cases the experiments were designed to determine the copper uptake of plants growing on soils treated with copper sulphate, and also the influence of soil reaction on copper uptake. On the characteristic soil from Robe it was shown that plants could secure some copper from various insoluble copper compounds. Copper carbonate, copper oxychloride, and three naturally-occurring copper minerals (cuprite, chalcopyrite, and atacamite) were used. A supply of low-grade ore is being tested in the field.

In pot experiments with a soil from McLaren Flat, where prune trees are suffering from a form of "little leaf", the use of indicator plants proved successful. Such plants have well-recognized symptoms for various deficiencies. The growing of oats, broad beans, sunflowers, and turnips on this soil led to the recognition of deficiencies in boron and in manganese. In the field boron deficiency has been confirmed with broad beans. This work is being done in collaboration with the Horticultural Branch of the Department of Agriculture.

3. Field Experiments.

The principal field experiments in connection with mineral deficiencies have been carried out at Robe and Meadows. Additional investigations are planned for Wood's Well and Kangaroo Island.

At Robe, where the existence of copper deficiency was already known, the additional deficiency of zinc has now been confirmed. To this must be added the deficiency of cobalt of importance to livestock. In previous experiments on two sites in the Robe district copper dressings alone had not overcome the difficulty of establishing certain pasture species and producing good crops. Several pasture plants have now shown responses to the application of zinc sulphate in the field. These species include lucerne, barrel medic, black medic, perennial rye-grass, Wimmera rye-grass, annual canary grass, cereals, and the naturally-occurring grass Madrid brome.

Although lucerne had been established and had given satisfactory yields with the assistance of copper dressings, the yields were considerably improved by the inclusion of zinc in the copper fertilizer.

Previously barrel medic and certain other pasture legumes have failed in the experimental areas, even when heavy dressings of copper have been included in the fertilizer application. Remarkable growth has now been obtained with barrel medic on experimental areas treated with both zinc and copper. A dense sward was obtained in the first year, and seed production was good.

Promising results have been obtained with Rotenburger black oats, a variety which has a reputation in Europe for resistance to copper deficiency. This reputation has been confirmed.

For some years at Meadows, on the Kuitpo gravelly sandy loam, a characteristic ironstone gravelly soil, difficulties have been experienced in the establishment of a permanent stand of subterranean clover. So far the responses to liming have not been consistent, but there has been a good response to wood ashes. Attempts are being made to explain the effect.

4. Fertilizers.

For some years the fertilizer companies in South Australia have placed on the market a specially-prepared superphosphate containing manganese sulphate. There has been a consistent sale for this product, and the most recent development in 1940 has been the proposal to market a superphosphate containing 7 lb., 14 lb., or 28 lb. of copper sulphate per bag of 180 lb.

A survey has been made of the zinc content of a series of fertilizers representing all the important types used throughout Australia. The zinc was determined by the polarographic method. In superphosphate the zinc content appears to be never less than 550–600 parts per million, this zinc coming from the original phosphate rock. When sulphuric acid prepared from zinc blendes is used for the manufacture of the superphosphate, the zinc content may be as high as 1,000 parts per million. A dressing of one hundredweight thus supplies the equivalent of $\frac{1}{4}$ to $\frac{1}{2}$ lb. of zinc sulphate, which is of the same order as the amount of zinc removed per acre by the average wheat crop.

Most of the samples of sulphate of ammonia, potash salts, and of natural and synthetic nitrate of soda contained less than 10 parts per million of zinc.

6. VIRUS INVESTIGATIONS.

The main object of the investigations during the period under review has been to obtain more knowledge on the nature and properties of plant viruses.

1. Tobacco Mosaic Virus.

(1) *Inactivating Effect of Salicylate.*

During the course of an investigation into the effect of various salts on the precipitation of tobacco mosaic virus it was discovered that the salicylate ion inactivated the virus and at the same time brought about marked changes in the physical condition of the virus protein. These effects have been followed up in detail.

The rate at which the virus loses its infectivity has been determined for a number of concentrations of potassium salicylate. At a salicylate concentration of 1·0 molar the greater part of the virus is inactivated in half an hour. At a concentration of 0·34 M the rate is very slow, and at 0·1 M there is no measurable loss of infectivity over a period of 48 hours.

In all cases where inactivation takes place the rate has been found to be logarithmic. One consequence of this which is not usually recognized is that in a mathematical sense complete inactivation is only approached after infinite time. However, since the minimum quantity of virus which is needed to cause infection consists of many virus particles, complete biological inactivation may be obtained in practice in a short time.

Mixtures of virus with salicylate remain clear at those salicylate concentrations at which the virus is not inactivated and at high concentrations (about 1 M and higher). In between these extremes the inactivated virus is precipitated as a white amorphous solid which does not redissolve in water like the infective virus. It will, however, dissolve in higher concentrations of salicylate. The virus precipitated in this way contains no phosphorus, one of the effects of the salicylate being to split off the nucleic acid from the molecule of the virus protein.

The effect on the virus of compounds chemically similar to salicylate is being investigated in the hope of obtaining some information about the particular chemical groupings which take part in the reaction.

(2) *Long-range Storage of Virus and the Constancy of Chemical Composition.*

In carrying out a programme of work extending over a period of years it is important to be able to use preparations which are standard in respect to infectivity and chemical composition. For this and other reasons purified virus preparations made over a period of years have been compared on the basis of infectivity per unit weight and proximate chemical composition. The infectivity per unit weight has been found to be the same within the experimental error of the primary lesion method. The chemical composition is also constant within the limits of experimental error. Average figures for the percentage of major components based on eight samples collected in 1936, 1938, 1939, and 1940 are C, 51·5; H, 7·0; N, 16·6; P, 0·51; S, 0·2; Ash, 1·2. Also solutions of virus extracted from plants harvested in July, 1935, have been tested for infectivity at intervals ever since. Solutions were made of infective juice and of purified virus in buffer solutions of various pH values. Some of these are as infective at the time of writing as they were when first prepared.

(3) *The Amino-Acid Constitution of the Virus.*

A knowledge of the nature and relative proportions of the amino acids of which the virus is composed will help towards a better understanding of the virus itself and of its mode of reproduction in the plant, and may also be expected to tell us something about the way in which the normal proteins are built up in the plant. Work on the amino-acid make-up of the pure virus has therefore been begun in collaboration with the Animal Nutrition Laboratory of the Council for Scientific and Industrial Research.

The tyrosine and tryptophane contents have been found to be 3·7 per cent. and 2·1 per cent. respectively. The 0·2 per cent. sulphur is present mainly as cystine (which constitutes 0·7 per cent. of the protein) and a doubtful trace of methionine.

2. Effect of Salicylate on Animal Viruses.

Because of the inactivating action of salicylate on plant viruses it was considered worth while testing the effect on animal viruses. Accordingly, arrangements were made with the Institute of Medical and Veterinary Science for a joint attack on the problem. This collaborative work has revealed that the viruses of herpes, Shope fibroma, vaccinia, and infectious myxoma are rapidly inactivated

when brought into contact with solutions of potassium salicylate. In all cases more than 99 per cent. of the virus was rapidly inactivated at salicylate concentrations between one-tenth and one-fifth molar. The rate of inactivation for Shope fibroma was determined and, like that for tobacco mosaic virus, was found to be logarithmic. Some exploratory work was also done on the effect of salicylate on the virus of Poliomyelitis and the possible use of salicylate-inactivated myxoma virus as an immunizing agent, but nothing definite has come out of these so far.

3. Tomato Spotted Wilt.

Potassium salicylate at a concentration of one-tenth molar was found to inactivate the virus rapidly, but detailed work of the kind done with tobacco mosaic has been postponed until the attempts to obtain purified samples of this virus have been carried further.

4. Identity of Fluorescent Substance.

The structure of the fluorescent substance described in previous reports has been established and the substance identified as 6-methoxy 7-hydroxy 1 : 2 benzopyrone. During the investigations which led to its identification many properties of the substance were determined, and some interesting reactions have been followed.

The substance is described in the literature as a constituent (probably inert) of certain medicinal plant extracts (from *Scopolia Japonica* and *Gelsemium sempervirens*), but very little work had been done on it.

Because the substance accumulates in larger amounts in injured plant tissues it was of some interest to know whether it was likely to photosensitize animals ingesting it. The Division of Animal Health and Nutrition of the C.S.I.R. has investigated this possibility and found that the substance had no photosensitizing activity.

7. THE CHEMISTRY OF PASTURES.

Chemical work on pastures falls mainly into two divisions—one designed to interpret the behaviour of pastures in terms of the environment and fertilizer needs of plants themselves, and the other as a means of assessing the value of the pasture as food for stock. While the fundamental work in this second direction falls primarily within the scope of the Animal Nutrition Laboratory of the Council for Scientific and Industrial Research there is need to bridge the gap between the work of the pasture ecologist and that of the biochemist. Investigations have been carried out therefore relating to the chemical composition and digestibility of the various types of pastures grown at the Waite Institute and elsewhere.

The uptake of the plant nutrients nitrogen and phosphorus, by mixtures of Wimmera rye-grass and subterranean clover and of *Phalaris tuberosa* and lucerne, was followed during the course of pot experiments, in which these species alone and in pairs were subjected to fertilizer treatment with various levels of nitrogen and phosphate and to various frequencies of cutting.

Creeping saltbush (*Atriplex semibaccatum*) has been suspected in South Africa of containing cyanogenetic substances liable to cause poisoning in sheep. In view of the importance of this species in the marginal agricultural country it was considered desirable to examine the plant grown at Pallamana at several stages of growth. The presence of hydrocyanic acid could not be established in very young material, while in older plants it was definitely absent.

In connection with the work on pasture management, chemical analysis of the pastures and the digestibility of the pasture samples as measured by the standard

practice of feeding to sheep have been determined. The first group of trials was made on the hay harvested in the spring months under the several systems of management.

The second group of trials was carried out with pasture cut green at monthly and bi-monthly intervals, the fresh green material being fed to sheep in metabolimeter cages over a period of three weeks. The experimental period was restricted to the last two weeks of each trial. These trials give for the first time a measure of the feeding value of the standard pasture of *Phalaris* and subterranean clover used at the Waite Institute.

The general type of results obtained are indicated below:

No. of trial.	Date of trial.	Botanical composition. Grass. %	Clovers. %	Misc. %	Dry matter in pasture. %	Protein in dry matter. %	Digestibility of protein. %
Monthly cuts:							
2	Aug. 9–22	46	47	7	15·7	27·6	83
4	Oct. 4–17	54	41	5	17·5	20·6	78
6	Dec. 1–13	94	0	6	29·1	13·8	72
Bi-monthly cuts:							
2	Aug. 9–22	53	32	15	13·4	22·4	84
4	Oct. 4–17	57	28	15	15·1	14·8	76
6	Dec. 1–13	94	0	6	29·6	12·6	74

In addition to determinations on crude fibre, ether extract and ash, estimates of the digestibility of cellulose and lignin are also being made.

Bacteriology

Since the beginning of 1935 the subject of bacteriology has been developed at the Waite Institute in two directions: the investigations of wine makers' problems brought forward by the Australian Wine Board and the study of the nodule organism of leguminous plants.

The bacterial spoilage of Australian fortified wines has been the subject of further study during the last two years. Several bacteria belonging to the genus *Lactobacillus* commonly occur in wines and lees, but only some of these are sufficiently tolerant towards alcohol to develop in fortified wines. Wines vary remarkably in their susceptibility to bacterial attack, and it has been shown that bacterial growth is stimulated by the presence of accessory growth factors which appear to be liberated during the autolysis of yeast cells in the lees. The degree to which autolysis occurs, and hence the susceptibility of the wine, is affected by the pH of the must, the temperature during and following primary fermentation and the length of time the wine is left in contact with the lees. The bacteria grow little, if at all, in wines with a pH below 3·6, but, owing to the effect of pH on the autolysis of yeast cells in the lees, the addition of tartaric acid to the must is more effective than a similar addition to the finished wine.

The bacteria fail to grow in wines containing 100 p.p.m. of SO_2, and growth is checked appreciably by the addition of tannin to the must or wine.

Control measures based on the foregoing are giving very promising results in commercial wineries.

At the request of the Australian Wine Board, investigations concerning the improvement of the quality of Australian sherry are being carried out. "Fino" sherry or wine matured under the influence of the so-called sherry "flor" (a film-forming yeast) is an important constituent of the "pale dry" sherries of Spain. The changes brought about in wine by the growth of film-forming sherry yeasts and the relationship of these changes to the characteristic flavour and "bouquet" of sherry are being studied.

The bacteriological section of the Division of Soils has continued the investigations on particular aspects of symbiotic nitrogen fixation. These have been chiefly the following:

(1) Strain variation, with particular reference to strains of *Rhizobium meliloti*, and the competition of effective and non-effective strains. The results which have been obtained during the past two years have strongly supported the view formed previously during the researches into strain variation of the *R. trifolii* group, that the host plant is the most important factor determining whether a strain is effective or non-effective. No strains within the new plant groups tested have proved non-effective in the absolute sense. A compatible host plant for the strain apparently parasitic on one particular host has always been found.

Strains effective for the peanut, for lima bean, and for the ground nut (*Voandzeia subterranea*) have been isolated and successful inoculation of the latter two species is now readily effected. The problem of a pot technique suitable for studying the symbiosis of tropical legumes under our normal glasshouse conditions of the summer is proving difficult.

The possible antagonism or competition of non-effective and effective strains has been further studied. In each case tested the effective strain has dominated, and, even when introduced six weeks after the non-effective strain, has readily entered the host plant and produced an immediate recovery from nitrogen deficiency. This aspect is of considerable importance in many cases in South Australia where pastures are being established.

(2) The drying of cultures. The technique of drying cultures under vacuum has been adopted and used for storing strains. It may prove possible to modify the technique and to adapt it for practical seed inoculation. Cultures have been dried out upon various protective colloids, and studies of the viability of the product have been made. A high degree of efficiency in seed inoculation for field purposes can be obtained when the powder is dissolved in water immediately after the vacuum of the sealed tubes is opened. The technique may prove practicable for field purposes if the rapid loss of viability on exposure of the powder to air can be avoided. This aspect is being studied.

The practical problem of establishing legumes on the poor lateritic soils of Kangaroo Island has been further studied, and now the results are promising. Copper deficiency has been an important factor limiting seed production by legumes in many areas. The factors influencing successful inoculation in these "difficult" soils have been fully studied from practical aspects. A close contact with various pioneers endeavouring to bring poor soils into production has been continuously maintained.

There has been a persistent demand by farmers for cultures for the inoculation of field legumes. A record number of cultures was supplied in the season of 1940.

Climatology

In the study of the geographical distribution of plants, animals, and soils, and in the determination of general agricultural policies, a knowledge of climatic conditions is of fundamental importance. The factors which are of greatest significance are the amount, distribution, and reliability of the rainfall and the temperature and humidity. The rate of evaporation has been found to be an important factor determining the efficiency of the rainfall and the water requirements of plants.

It has been generally assumed that the saturation deficit of atmospheric vapour pressure is the most important factor controlling evaporation, but an ex-

amination of available records has shown that the rate of evaporation is also controlled by solar radiation.

In connection with the work of the Institute in both the pastoral and the more closely settled regions, an examination is being made of South Australian rainfall records to characterize the frequency distribution of rainfall, with the ultimate object of determining the amounts of annual and seasonal rainfall which can be expected in given periods of years.

During the period under review in this report considerable progress has been made in the work relating to the investigation of annual rainfall. The analysis of rainfall records from the following parts of the State has been completed: Far North (interior), North-East, Upper North (western and eastern), Far North-West (interior), districts west of Spencer's Gulf, and the most northerly sections of the Lower North.

In 1940 a detailed investigation of trend in the yield of wheat and the relationship between yield and seasonal rainfall was begun. The analysis of data obtained from the wheat-growing areas of counties Blackford, Hanson, Newcastle, Granville, and the most northerly hundreds of counties Frome and Dalhousie, has been completed.

From a consideration of the monthly rainfall and saturation deficiency for twenty South Australian stations at which wet and dry bulb temperatures had been recorded for a sufficient period of years, the variation in the duration of the winter rainfall season and the amount of influential rainfall has been determined.

Waite Arboretum

Under the deed of gift of the late Mr. Peter Waite it was provided that portion of the area containing 67 acres should be held in perpetuity as a park, provided that a portion, not exceeding 15 acres, might be set apart for the purpose of a sports ground for graduates and undergraduates of the University. Effect has been given to both of these provisions. It was decided that the best means of carrying out the terms of the gift would be the establishment of an arboretum in which trees should be grown as specimen trees to demonstrate their value for shelter or ornamental purposes, and their adaptability to the local soil and climate.

The original natural vegetation was in itself park-like, being an open savannah woodland of *Eucalyptus odorata*, and this gave promise of success in the establishment of such an arboretum.

Owing to the long, dry summer characteristic of the Adelaide environment, trees to be successful must be capable of enduring drought for some five months of the year. In the early years, however, provision has been made for the watering of all the trees. The practically complete absence of frost in the site chosen for the arboretum has probably extended the range of species likely to be found suitable. This applies more particularly to the drought-resisting tropical trees from the monsoonal regions.

Considerable interest has been shown in the development of the arboretum by district and municipal councils, particularly with respect to the choice of trees suitable for street planting. Of these the most promising have proved to be *Ficus Hillii, Vitex lucens, Tristania conferta, Flindersia australis,* and *Bauhinia purpurea.*

There are 1,020 young trees in all, belonging to about 390 different species. Most of the trees were planted in the period 1928–30, but many additions and replacements are constantly being made.

So that the collection shall have its maximum usefulness for demonstration purposes, all the trees are labelled with their names, habitat, and year of planting.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at three centres: at the Waite Institute itself, at Pallamana in the Murray Mallee, north-west of Murray Bridge, and at Yudnapinna, north-west of Port Augusta. In these two latter centres the observations are associated with the work on pasture regeneration in the more arid regions under the terms of the Ranson Mortlock Trust.

At the Waite Institute readings are taken at 9 a.m. daily, and include maximum and minimum temperatures, wet and dry bulb temperatures, maximum black bulb solar temperature, rainfall, evaporation, wind mileage, and barometric pressure. In addition, self-recording instruments deal with wind direction and velocity, and with soil temperatures at depths of one inch, six inches, twelve inches, and twenty-four inches.

Since the beginning of 1938 a self-recording rain gauge has been in operation. Each hundredth of an inch of rain falling on the gauge is recorded electrically in the laboratories.

Evaporation is measured from the free water surface of an open tank, 36 inches in diameter and 36 inches deep, with a surrounding guard-ring six inches wide. The mean monthly values for rainfall, evaporation, and air temperatures for the two years 1939 and 1940 are given below, the individual records for the years 1925–38 having been presented in previous reports.

Monthly Rainfall and Evaporation in Inches for the years 1939–40, Waite Institute.

	Rainfall.		Evaporation.	
Month.	1939.	1940.	1939.	1940.
January	1·176	1·492	10·443	7·577
February	1·970	0·543	7·629	7·223
March	1·560	0·667	5·611	7·437
April	2·532	3·783	3·812	3·786
May	2·518	1·069	2·521	2·386
June	5·054	1·067	1·455	1·603
July	2·430	3·849	1·769	1·523
August	4·743	1·744	1·896	2·666
September	1·525	1·684	3·085	3·450
October	1·176	0·699	4·801	5·317
November	4·016	1·970	5·077	5·439
December	0·283	1·301	6·554	7·867
Total	28·983	19·868	54·653	56·274

Mean Monthly Air Temperatures for the Years 1939–40, Waite Institute.

Month.	Solar max.	Screen max.	Screen min.	Solar max.	Screen max.	Screen min.
		1939.			1940.	
	°F.	°F.	°F.	°F.	°F.	°F.
January	150·3	90·5	67·1	142·6	79·4	58·6
February	141·0	84·6	62·8	141·4	79·2	58·2
March	137·3	76·7	58·8	143·6	86·3	66·0
April	132·2	70·8	56·5	126·6	67·6	53·3
May	119·7	67·3	54·0	116·0	61·5	48·5
June	110·5	59·8	48·3	108·6	58·5	45·8
July	107·9	56·7	45·4	103·5	57·7	46·2
August	116·0	57·5	44·7	118·8	61·0	45·9
September	124·7	62·1	47·8	127·0	64·9	47·9
October	133·3	69·6	51·4	134·5	73·5	54·5
November	139·5	70·7	54·5	134·5	70·0	51·9
December	141·6	73·3	53·8	140·9	80·9	59·0
Mean	129·5	70·0	53·8	128·2	70·0	53·0

Soil Temperatures.

Temperatures in soil in bare fallow are recorded continuously by means of mercury in steel self-recording thermographs.

The mean monthly maximum and minimum soil temperatures for sixteen years are summarized in the following table:

Mean Monthly Soil Temperatures at 1 inch, 6 inches, 12 inches, and 24 inches for Sixteen Years, 1925–40, Waite Institute.

	At 1"		At 6"		At 12"		At 24"	
Month.	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.
January	110·3	64·4	85·9	72·2	78·0	72·6	74·3	71·2
February	107·5	64·1	84·8	71·7	77·5	72·3	74·9	72·0
March	101·7	62·3	80·9	69·3	74·9	68·9	73·4	70·5
April	83·9	55·5	69·9	61·3	66·9	63·3	67·8	65·0
May	71·5	50·7	61·5	54·8	60·2	57·3	61·8	59·6
June	63·7	47·1	55·8	50·6	55·0	52·4	56·6	54·9
July	62·0	46·1	54·1	49·2	53·2	50·6	54·4	52·7
August	65·6	47·1	56·5	50·6	54·1	51·3	54·7	52·7
September	74·0	50·1	62·3	54·4	58·5	55·0	57·8	55·5
October	85·1	54·7	70·2	59·7	64·4	60·1	62·5	59·9
November	97·4	59·5	78·1	65·3	70·6	65·6	67·6	64·8
December	106·4	62·7	83·3	69·7	75·2	69·9	71·7	68·8
Mean	85·8	55·4	70·3	60·7	65·7	61·6	64·8	62·3

Number of Hours of Bright Sunshine.

The number of hours of bright sunshine is recorded daily by means of a Campbell-Stokes sunshine recorder, and is summarized in the following table:

Mean Number of Hours of Bright Sunshine per Month and per Day for Sixteen Years, 1925–40, Waite Institute.

Month.	Number of hours per day.	Number of hours per month.
January	8·8	273
February	8·6	244
March	7·5	234
April	5·6	167
May	4·3	134
June	3·4	101
July	3·2	101
August	4·4	137
September	5·7	171
October	6·7	207
November	8·0	241
December	8·4	260
	Mean 6·2	Total 2,270

General Climatological Data.

The most important data on which the studies of climatology are to be based involve rainfall, evaporation, temperature, relative humidity, and atmospheric saturation deficit.

Evaporation from a free water surface is mainly dependent on saturation deficit and solar radiation. Evaporation may be regarded as proportional to saturation deficit when comparisons made of two or more localities relate to the same month. The ratios of rainfall to evaporation or of rainfall to saturation

deficit have been found of special value in agroclimatological and bioclimatological studies.

The essential data for the Waite Institute, based on the mean values for the sixteen years 1925–40, are given in the following tables:

Month.	Rainfall. inches.	Evaporation. inches.	Temperature. Max. °F.	Min. °F.	Mean °F.	Relative humidity per cent.	Saturation deficit. Inches of mercury.	Ratio rainfall / evaporation.
January	0·89	8·82	81·1	60·1	70·6	52	0·37	0·101
February	1·05	7·19	81·4	60·8	71·1	53	0·36	0·146
March	0·93	6·66	79·1	60·2	69·6	52	0·36	0·140
April	2·09	4·09	70·3	54·4	62·3	63	0·20	0·511
May	2·97	2·89	64·4	50·7	57·5	68	0·15	1·030
June	3·01	1·82	58·6	46·4	52·5	75	0·10	1·656
July	3·02	1·81	57·3	45·4	51·3	76	0·09	1·670
August	3·21	2·38	59·0	45·9	52·4	71	0·12	1·348
September	2·60	3·30	63·6	48·1	55·9	66	0·15	0·789
October	1·65	4·82	68·8	51·1	60·0	60	0·21	0·342
November	1·34	6·47	74·4	55·1	64·7	55	0·28	0·208
December	1·06	8·01	78·5	57·6	68·0	52	0·34	0·132
Total	23·82	58·26	Mean 69·7	53·0	61·3	62	0·21	0·409

In the course of investigations the monthly values of the ratios of rainfall to evaporation have proved to be most instructive. With a ratio of 1, rainfall and evaporation as measured from a free water surface are, of course, equal. A value for this ratio of 0·5 has been found to be useful in bioclimatic studies, while for agroclimatic studies ratios of 0·33 to 0·25 have been found to indicate the lower useful limit of monthly rainfall.

The mean monthly values for these ratios are given above. The following table gives the length of the season during which the above-mentioned ratios are maintained. The agricultural season may be assumed to be determined by the period during which the ratio of rainfall to evaporation exceeds 0·33.

Length of Season in Months during which certain Ratios of Rainfall to Evaporation are Exceeded, Waite Institute.

	R/E.	R/E.	R/E.	R/E.
Ratio	1·00	0·50	0·33	0·25
Length of period (months)	3·7	5·7	6·6	7·4

Observations at Country Centres.

Monthly Rainfall and Evaporation in Inches for the Years 1938–40, Pallamana.

Month.	Rainfall. 1938.	1939.	1940.	Evaporation. 1938.	1939.	1940.
January	0·470	0·870	0·580	9·119	10·932	9·292
February	1·140	2·210	0·270	7·385	8·387	8·933
March	0·300	0·040	0·360	7·213	6·497	9·267
April	1·930	1·225	1·410	4·554	3·916	4·327
May	0·335	0·850	0·560	2·769	2·604	2·630
June	1·350	2·255	0·405	2·048	1·586	2·072
July	1·805	1·160	0·880	1·384	1·643	1·885
August	1·700	2·300	0·765	2·346	2·495	3·588
September	0·295	0·260	1·140	4·282	3·944	4·999
October	0·390	0·705	0·510	7·023	5·746	7·083
November	0·505	3·145	0·685	8·390	6·387	8·317
December	0·050	0·080	1·315	9·470	9·111	10·291
Total	10·270	15·100	8·880	65·983	63·248	72·684

Mean Monthly Air Temperatures and Relative Humidity for the Years 1938–40, Pallamana.

	Air Temperatures.						Relative Humidity.		
	Max.	Min.	Max.	Min.	Max.	Min.	per cent.		
	1938.		1939.		1940.		1938.	1939.	1940.
Month.	°F.	°F.	°F.	°F.	°F.	°F.			
January	82·1	56·2	90·4	61·4	81·3	55·1	48	45	59
February	82·3	56·7	86·0	57·9	81·5	54·1	49	55	58
March	79·8	56·4	78·0	53·8	88·4	56·2	62	65	45
April	76·2	51·8	72·4	51·3	67·1	48·8	68	82	70
May	67·6	45·4	67·7	46·8	62·1	43·7	75	87	79
June	60·9	40·2	60·4	43·5	60·3	39·6	79	93	85
July	59·1	39·6	57·3	39·4	58·1	41·4	85	96	86
August	62·4	40·2	59·9	42·3	63·3	39·4	80	91	78
September	70·0	42·8	65·3	43·0	67·4	43·4	60	64	66
October	74·7	47·9	72·0	44·9	76·0	49·8	48	60	57
November	80·7	52·0	71·9	51·8	73·2	50·0	44	63	54
December	82·8	55·4	75·7	51·7	83·2	55·7	47	51	50
Mean	73·2	48·7	71·4	49·0	71·8	48·1	62	71	66

Monthly Rainfall and Evaporation in Inches for the Years 1939–40, Yudnapinna.

	Rainfall.		Evaporation.	
Month.	1939.	1940.	1939.	1940.
January	0·740	0·850	16·725	14·565
February	1·165	0·120	12·777	13·681
March	1·305	0·210	9·628	13·316
April	0·020	0·330	7·448	6·686
May	0·760	0·590	4·380	4·595
June	1·405	0·055	2·777	3·251
July	0·645	0·445	2·564	3·605
August	0·620	0·230	3·127	5·359
September	0·135	0·410	4·859	7·410
October	0·070	0·450	10·015	11·306
November	1·535	0·060	10·424	12·416
December	0·040	0·245	13·724	13·889
Total	8·440	3·995	98·448	110·079

Mean Monthly Air Temperatures and Relative Humidity for the Years 1939–40, Yudnapinna.

	Air Temperatures.				Relative Humidity.	
	Max.	Min.	Max.	Min.	per cent.	
	1939.		1940.		1939.	1940.
Month.	°F.	°F.	°F.	°F.		
January	100·4	71·3	91·6	62·5	57	65
February	92·8	66·9	89·2	62·8	52	43
March	83·2	60·1	93·3	62·3	52	34
April	76·6	54·2	71·7	50·3	70	56
May	71·0	49·7	66·7	48·2	63	67
June	63·0	44·1	64·7	41·0	78	67
July	59·1	41·8	62·7	41·9	80	67
August	64·9	42·3	66·7	41·6	72	61
September	71·1	44·6	72·1	46·2	57	48
October	77·4	51·3	83·8	55·4	44	44
November	81·5	57·7	83·7	53·1	55	46
December	86·7	57·4	91·5	62·1	50	36
Mean	77·3	53·4	78·1	52·3	61	53

The Soil Profile at the Waite Institute

The soil of the experimental fields at the Waite Institute is typical of a group of South Australian soils known as the red-brown earths. The profile has been developed on an alluvial fan at the foothills of the Mount Lofty Ranges, and the parent material is derived from the adjacent pre-Cambrian shales and slates. The surface horizon consists of a friable brown loam with a very pronounced fine sand fraction. With increase of depth the amount of organic matter falls off, and the colour of the mineral fraction predominates. The soil gradually changes to a reddish brown at 12–18 inches, while the deep clay is red.

Eluviation has not been sufficient to remove the calcium carbonate entirely from the lower horizons of the profile, although the surface soil is weakly podsolized. The reaction of the surface soil is pH 6·0 to 6·3, while that of the carbonate horizon may reach pH 8·6.

The mechanical composition of the several horizons reveals the nearly constant proportion of coarse sand, fine sand, and silt throughout the profile, and shows clearly the uniform nature of the original parent material. These three fractions constitute the non-colloidal framework of the soil, and their constant proportion shows that the changes in the colloidal fraction (clay) of the different horizons has been brought about by a process of eluviation. The accumulation of clay in the B_1 horizon has occurred as a result of its dispersion and mechanical eluviation under the slightly acid conditions existing in the surface soil. An examination of the silica : sesquioxide ratios shows that there has been only a small amount of leaching of the sesquioxides from the surface layers into the lower horizons. The amount of free ferric oxide in the different parts of the profile also shows that there has been little actual decomposition of the clay to silica and sesquioxide, as occurs in podsols.

Organic carbon and nitrogen decrease progressively throughout the profile, and the carbon : nitrogen ratio changes from about 13 in the surface horizon to a value of 7–8 at a depth.

Although the soils are somewhat unsaturated with bases in the surface horizons, the values ranging from 60–65 per cent. of full saturation, the percentage saturation increases progressively with depth, and the horizons below the appearance of calcium carbonate are fully base saturated. Calcium is the dominant exchangeable base in the surface soil, and accounts for the good texture in the field. The proportion of magnesium, however, increases considerably in the subsoil. Exchangeable sodium is low throughout the profile, indicating that the leaching conditions and calcium status of the soil are sufficiently good to remove cyclic salts, without an accumulation of exchangeable sodium. The quantities of exchangeable potassium indicate that the soil is well supplied with this element in a form available for plant growth.

The Mechanical and Chemical Analyses of a Typical Red-Brown Earth Profile at the Waite Institute.

Locality.		Hd. Adelaide, Section 250.						
Soil No.		U151	U152	U153	U154	U155	U156	U157
Depth		0–4″	4–9″	9–18″	18–27″	27–36″	36–45″	45–54″
Horizon		A_1	A_2	B_1	B_1	B_1	B_2C	B_2C
Reaction	pH	6·0	5·8	6·3	6·7	7·2	8·4	8·6
		%	%	%	%	%	%	%
Calcium carbonate	$CaCO_3$	0·02	tr.	0·01	nil	0·13	4·80	3·96
Mechanical analysis:								
Coarse sand		2·1	1·9	1·2	0·7	0·6	0·8	1·3
Fine sand		43·7	40·8	26·3	18·6	19·2	24·5	25·3
Silt		34·8	33·8	22·8	18·8	19·3	28·4	29·7
Clay		18·0	21·8	47·4	59·9	59·2	40·7	37·2
Loss on acid treatment		1·0	0·7	1·1	1·4	1·6	6·3	5·2
Moisture		0·4	0·6	1·2	2·0	1·7	1·2	1·1
Chemical data:								
Loss on ignition		4·4	4·1	6·2	7·3	7·2	7·3	6·7
Organic carbon	C	1·32	1·07	0·76	0·67	0·66	0·41	0·30
Humus		1·53	1·02	0·59	0·41	0·45	0·34	0·26
Free iron oxide	Fe_2O_3	2·14	2·46	4·68	5·17	4·72	3·42	3·34
Nitrogen	N	0·103	0·091	0·084	0·077	0·073	0·046	0·035
Phosphoric acid	P_2O_5	0·047	0·046	0·051	0·050	0·045	0·032	0·028
Potash	K_2O	0·52	0·59	0·93	1·11	1·08	0·90	0·93
Chlorides	as NaCl	0·013	0·008	0·008	0·010	0·012	0·015	0·016
Exchangeable bases:		m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%
Total bases		7·0	7·4	15·1	22·9	25·1	25·0	23·6
Exchangeable hydrogen	H	5·2	5·2	6·4	6·5	5·4	0·9	0·5
Proportions as		†	†	†	†	†	†	†
Calcium	Ca	64	65	59	57	60	71	68
Magnesium	Mg	19	23	32	34	32	22	25
Potassium	K	12	9	6	6	5	4	4
Sodium	Na	5	3	3	3	3	3	3
Percentage base saturation		57	59	70	78	82	97	98
Composition of clay fraction:								
$\frac{SiO_2}{Al_2O_3}$		3·43	3·27	2·86	2·85	2·86	3·16	3·22
$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$		2·53	2·41	2·13	2·12	2·13	2·32	2·34

m.e.% Milligram equivalents per 100 grm. of soil.

† Percentage composition of the bases.

Papers Published by the Staff of the Waite Agricultural Research Institute 1939-1940

I. SOIL CLASSIFICATION AND SOIL SURVEYS.

J. G. Baldwin, G. H. Burvill, and J. R. Freedman. C.S.I.R. Bull. 125. 1939. "A Soil Survey of Part of the Kerang Irrigation District, Victoria." (Reprint 268.)

A soil survey of 54,000 acres of the Kerang Irrigation District has been made with a view to forming a basis for future rehabilitation of the area. Increasing soil salinity, which has caused a loss of productivity since irrigation started, has made this necessary. The major soil types have been described, and their distribution shown on a soil map. Salt status of the soil and its relation to irrigation and vegetation, also the salt tolerance of many species of plants, have been examined in detail.

The present agricultural state of the district is described, and the course of its deterioration traced.

It is concluded that reclamation is thoroughly practicable, and the means of improvement are outlined.

A. B. Beck. Jour. C.S.I.R. *12*: 128. 1939. "The Relation between Colour and Chemical Composition in Soils." (Reprint 269.)

A study has been made of the relationship between the colours of 32 soils, and the calcium carbonate, humus, and free iron oxide contents.

In normal brown and red soils free ferric oxide and humus are the predominating colouring materials. Calcium carbonate causes a darkening of the colour due to humus in some soils. In grey, black, and white soils the free ferric oxide is probably very low. The yellow colour of some podsolic subsoils cannot be removed by treatment which removes free ferric oxide and appears to be intrinsic to the mineral colloid of the soil. In certain red soils of basaltic origin the colour seems to be due in part to the presence of a brown complex iron silicate.

J. S. Hosking and G. H. Burvill. C.S.I.R. Bull. 115. 1938. "A Soil Survey of Part of the Denmark Estate, Western Australia." (Reprint 260.)

A soil survey of an area embracing 25 square miles within the Denmark Estate, in the extreme southern portion of Western Australia, has been described.

The area is characterized: (a) vegetatively by karri, jarrah and marri, and moorland heath associations, (b) physiographically by high ridges, steep slopes, and open valleys, (c) geologically by a series of more or less metamorphozed acid igneous and sedimentary rocks, intruded by rocks of a more basic nature, and the very general distribution of laterite and ferruginous gravel throughout the surface horizons of the soils, (d) pedologically by soils which vary from true podsols, with well developed coffee rock or hardpan layers, through weakly podsolized types, to types showing certain affinities to those of the red-brown earths, and (e) enzootically by the incidence of a disease affecting cattle and sheep, which at one time seriously threatened the dairying industry of the district, but which has since been brought under complete control by the employment, in suitable form, of a cobalt supplement to the diet.

The extent, distribution, and inter-relationships of all these features are discussed in some detail.

In all, thirteen soil types, grouped into nine series and named, together with a further five groups of related soils of minor extent, have been identified and fully described.

J. S. Hosking. Aust. Chem. Inst. Jour. & Proc. *7*: 234. 1940. "The Constitution and Classification of the Clay Minerals." (Reprint 290.)

A survey has been made of the literature dealing with the compositions and structures of the minerals present in clays and the colloidal fractions of soils, and their classification in the light of this knowledge is given.

The clay minerals may be divided into the following groups: (a) kaolin minerals (b) montmorillonite minerals, (c) hydrous micas, with a subsidiary fourth group (d) accessory free oxides and hydrous oxides of silicon, iron, and aluminium.

J. S. Hosking. Jour. C.S.I.R. *13*: 206. 1940. "The Soil Clay Mineralogy of some Australian Soils Developed on Granitic and Basaltic Parent Material." (Reprint 299.)

The colloidal fractions separated from the subsoils of a number of Australian soils have been examined by means of X-ray diffraction technique, and their soil clay minerals identified.

Kaolinitic clay types characterize each one of a series of granitic soils examined, irrespective of the conditions under which they developed. In the case of a series of basaltic soils, however, the type of clay mineral present is a reflection of the soil moisture conditions under which they have delevoped; kaolinitic types alone characterize the red loams, montmorillonitic types, together with a little kaolinite, occur in the red-brown earths, while montmorillonite alone is typical of the black earths. Where climatic conditions would appear to lead normally to the development of the kaolinitic type, restrictions in free drainage are shown to produce a montmorillonitic clay on soils formed over certain basic rocks.

Accessory quartz, hydrargillite (Gibbsite), haematite, and goethite are also present in certain soils.

F. Penman, J. K. Taylor, P. D. Hooper, and T. J. Marshall. C.S.I.R. Bull. 123. 1939. "A Soil Survey of the Merbein Irrigation District, Victoria." (Reprint 252.)

A soil survey of 8,200 acres of irrigated land devoted chiefly to vine fruit production has been completed. Of the soil types found, many have been described in surveys of irrigation areas in the South Australian Murray Valley. Several new types have been named.

Chemical examination of the soils showed that all soils are alkaline, some very much so. In general character, the Merbein soils conform to the normal features of the Mallee group of soils.

Data on soluble salts show that sulphate is of greater importance in these soils than in the soils of other Murray irrigation areas. The relation of the soil types to water movement and drainage problems is also discussed.

F. Penman, G. D. Hubble, J. K. Taylor, and P. D. Hooper. C.S.I.R. Bull. 133. 1940. "A Soil Survey of the Mildura Irrigation Settlement, Victoria." (Reprint 295.)

The Mildura settlement is the oldest irrigation area in Australia. An area of 17,000 acres of mallee country, of which 11,000 acres are under horticultural crops, was covered by the soil survey. The Bulletin includes a soil map and a full description of the soils, many of which are different from those of all other Murray Valley settlements. The soils are inherently saline, and waterlogging, and salinity problems have been in evidence since the early years of the settlement. The installation of a comprehensive drainage scheme has rectified many of these troubles.

J. K. Taylor and P. D. Hooper. C.S.I.R. Bull. 118. 1938. "A Soil Survey of the Horticultural Soils in the Murrumbidgee Irrigation Areas, New South Wales." (Reprint 256.)

This Bulletin deals with the soils of the M.I.A., which are classified into five groups based on origin, topography, and profile. Nine soil maps are included. The structure of the soil horizons was found to be important in relation to irrigation. The problems in management, irrigation, waterlogging, and soil-crop relations are discussed. The Bulletin has served as a basis for recent studies on these problems as contributing to the decline of the area.

II. AGRICULTURAL CHEMISTRY—LABORATORY TECHNIQUE.

C. S. Piper. Aust. Chem. Inst. Jour. & Proc. *6*: 421. 1939. "The Use of Perchloric Acid in the Digestion of Plant Materials." (Reprint 275.)

Details are given of a method for the digestion of plant materials with a mixture of nitric, perchloric, and sulphuric acids. Silica, separated and dehydrated during the course of such digestion, is free from adsorbed manganese and copper. The siliceous residue remaining after the repeated hydrochloric acid extraction of plant ash obtained by various dry ashing procedures frequently contains significant proportions of these trace elements, and the use of hydrofluoric acid is essential to secure their complete solution. It is considered that many cases of alleged losses of particular elements during ashing are not real losses, but are due to the fixation of these elements in an insoluble form in the siliceous residue.

R. E. Shapter. Aust. Chem. Inst. Jour. & Proc. *7*: 155. 1940. "The Estimation of Phosphorus in Plant Material." (Reprint 286.)

In a previous paper the volumetric method for estimation of phosphorus, originally attributed to Pemberton, was investigated, and the advantages of wet digestion of plant material by means of nitric-perchloric-sulphuric acid became apparent. The use of such a method rendered the gravimetric method of Lorenz able to be carried out. This method was also investigated to determine the limits in phosphorus content within which accurate results could be obtained. Examination of the process was carried out over a wide range of phosphorus content, and under conditions similar to those encountered in the actual application of the method. The range of variation over which the method could be applied was found to be much greater than that over which the volumetric method was suitable. Much smaller amounts of phosphorus, being able to be estimated with accuracy. Some variations in the amount of phosphorus recovered were found. In general, if the ordinary Lorenz factor were used, results tended to be low, but in some cases they were high. The method has given considerable satisfaction in practice on samples of plant material having wide variation in phosphorus content.

Robert Smith. Jour. Aust. Inst. Agric. Sci. *6*: 197. 1940. "A Shaking Machine for the Separation of Sand Fractions." (Reprint 304.)

The sieving of sand samples by hand has several disadvantages, the chief of which are the tedium of the operation and the large personal factor involved in deciding on a suitable end point. The paper demonstrates that these difficulties can be largely overcome if the sieving is done by means of a mechanical shaker, using a standardized technique.

A. Walkley. Aust. Chem. Inst. Jour. & Proc. *6*: 310. 1939. "The Occurrence of Explosions during the Extraction of Peat Soils by Ether." (Reprint 276.)

Several explosions which occurred during the extraction of fats and waxes from a peat soil are considered to have been due to the presence of peroxides in the ether. Some ethers of inferior quality contain sufficient moisture to enable oxidation to proceed fairly rapidly, particularly in warm weather.

The amounts of such impurities present in the ether are shown to be very small, but it seems possible that during the soil extraction still more peroxide may be formed until eventually an explosive concentration is attained.

D. C. Wark. Jour. Aust. Inst. Agric. Sci. *5*: 224. 1939. "Tests on Plant Tissue as a Guide to the Soil's Available Nutrients." (Reprint 278.)

The presence of phosphate or nitrate as inorganic salts in certain localized parts of the plant may be detected by rapid colorimetric tests.

These tests on the plant tissue indicated the relative abundance of nitrogen and phosphate in an available form in the soil. The colours developed were related to the amounts of superphosphate and of sulphate of ammonia applied to wheat, oats, barley, and peas in a manurial and rotation experiment at the Waite Institute.

III. MINERAL DEFICIENCIES.

C. S. Piper. Jour. Aust. Inst. Agric. Sci. *6*: 162. 1940. "Molybdenum as an Essential Element for Plant Growth." (Reprint 298.)

The essential nature of molybdenum for plant growth has been confirmed by water culture experiments with Algerian oats. In the absence of molybdenum, panicles formed, but the grain consisted of empty husks only. 0·02 mg. of molybdenum per litre of nutrient solution ensured normal growth and grain formation. In one experiment, in the absence of molybdenum, 11·9 gm. of empty husks were produced, whereas in its presence the yield was 35·8 gm. of well-filled grain.

A. Walkley. Jour. C.S.I.R. *13*: 255. 1940. "The Zinc Content of Some Australian Fertilizers." (Reprint 305.)

Fertilizers representing all of the important types used throughout Australia have been examined for the zinc which they contain as a chance "impurity". The zinc is determined by the polarographic method either with or without a preliminary dithizone separation.

In superphosphates the zinc content appears to be never less than 550–600 p.p.m., this zinc coming from the original phosphate rock. When sulphuric acid prepared from zinc

blendes is used for the manufacture of superphosphate, the zinc content may be as high as 1,000 p.p.m. A dressing of 1 cwt. thus supplies the equivalent of ¼ to ½ lb. of zinc sulphate, which is of the same order as the amount of zinc removed per acre by the average crop of wheat.

Superphosphates also contain cadmium in amounts (50–170 p.p.m.) which are large in relation to the zinc and the other heavy metals.

Most of the sulphate of ammonia samples, the potash salts, and the natural and synthetic nitrate of soda contained less than 10 p.p.m. of zinc.

C. S. Piper. Emp. Jour. Exp. Agric. *8*: 85. 1940. "The Symptoms and Diagnosis of Minor-element Deficiencies in Agricultural and Horticultural Crops. Pt. 1. Diagnostic Methods. Boron. Manganese." (Reprint 292.)

The difficulties of diagnosis by chemical analysis of the soil are discussed, and the importance of the recognition of specific symptoms on suitable "indicator plants" is stressed. Pot experiments and water cultures are of considerable assistance in the study of deficiencies. The more important symptoms of boron and manganese deficiencies in different crops are described.

C. S. Piper. Emp. Jour. Exp. Agric. *8*: 199. 1940. "The Symptoms and Diagnosis of Minor-element Deficiencies in Agricultural and Horticultural Crops. Pt. 2. Copper, Zinc, Molybdenum." (Reprint 301.)

Two groups of copper deficiency diseases are described: namely, "dieback" or "exanthama" of fruit trees, and "reclamation disease". The leaf symptoms induced by growing wheat, oats, and many other plants in copper-free nutrient solutions correspond to those exhibited by plants growing on naturally deficient soil. Extreme copper deficiency limits vegetative growth as well as seed formation. The symptoms of naturally-occurring zinc deficiency diseases are described, and also the symptoms shown by oats when grown in nutrient solutions devoid of either zinc or molybdenum.

D. S. Riceman and C. M. Donald. Jour. Agric. Sth. Aust. *42*: 959. 1939. "Copper Response on 'Coasty' Calcareous Soils in South Australia." (Reprint 262.)

The "coasty" soils of the South-East of South Australia and their associated pastures are described. Evidence is submitted to show that oats, wheat, barley, and lucerne sown thereon respond to field applications of copper sulphate. Practical recommendations concerning the treatment of these soils with copper are given.

D. S. Riceman, C. M. Donald and S. T. Evans. C.S.I.R. Pamph. 96. 1940. "Further Investigations on Copper Deficiency in Plants in South Australia." (Reprint 296.)

Earlier results demonstrating acute copper deficiency on "coasty" calcareous soils are confirmed. The application of copper sulphate enables oats, wheat, and cultivated herbage plants to be grown successfully; residual effects on permanent pasture have been recorded. The provision of copper alone, however, does not appear to be sufficient for maximum growth.

There were considerable differences in the susceptibility of different crop and pasture species to copper deficiency, and in their response to applied copper.

The concentration of copper in susceptible cereals was not increased by field applications of copper, but increases in concentration were obtained in pot cultures, particularly with *Avena strigosa* and *Secale cereale*.

A. Walkley and H. K. Kemp. Jour. Aust. Inst. Agric. Sci. *5*: 229. 1939. "The Occurrence of Boron and Manganese Deficiencies in a Sandy Soil." (Reprint 277.)

An attempt has been made by means of pot experiments to assist in the diagnosis of a disease of prune trees which occurs on a very light soil at McLaren Flat, near Adelaide. The disease appears to be very similar to "little leaf" or "rosette", reported overseas as due to zinc deficiency, but it has not responded in any way to zinc sprays or soil dressings of zinc.

Several annual plants when grown in this soil have developed well-recognized symptoms of boron and manganese deficiencies. Boron deficiency symptoms were well marked in turnips, and manganese deficiency symptoms in oats. In no cases did they appear when boron or manganese was added to the soil.

IV. PLANT VIRUSES.

R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. *17*: 1. 1939. "The Preservative Effect of Some Reducing Systems on the Virus of Tomato Spotted Wilt." (Reprint 255.)

Under ordinary conditions suspensions of tomato spotted wilt virus lose their infectivity in a few hours at room temperatures. Certain reducing agents prolong the *in vitro* life of this virus. Hydrogen in the presence of platinized platinum arrested the normal aerobic inactivation of the virus, and thereafter maintained the activity at a constant level for the duration of the experiment (eight hours).

Suspensions of the virus in a buffer solution in the presence of cystein and absence of free oxygen have been kept in an active state for 35 days, as compared with a normal *in vitro* life of five hours.

The sodium salts of glutathione, thioglycollic acid, and ascorbic acid (all buffered at pH 7) preserved the virus against rapid aerobic inactivation.

Adrenaline had no significant effect on the activity of suspensions exposed to air, but protected the virus against the slow inactivation which takes place in the absence of oxygen. Redox potentials of the test systems are recorded and discussed in relation to the relative efficiencies of the protective agents.

R. J. Best. Jour. Aust. Inst. Agric. Sci. *5*: 94. 1939. "Virus Activity as a Property of Some Protein Molecules." (Reprint 267.)

A comparative study of the properties of some plant viruses with special reference to physico-chemical relationships.

The "layering" phenomenon observed with solutions of tobacco mosaic virus in water was shown to depend in a stoichiometric manner (at constant pH value and temperature) on the concentration of virus and concentration of electrolyte. Other curves illustrate the influence of redox potential and pH value on the *in vitro* activity of tomato spotted wilt virus.

A possible mechanism by which a virus may multiply is outlined. The virus molecule is regarded as a template. By means of its surface electronic forces it would attract to the surface from its environment the essential building blocks which go to make up its structure. As each block is assembled the surface forces would be re-arranged, and so the process would go on until an exactly similar molecule is built up.

R. J. Best. Jour. Aust. Agric. Sci. *5*: 162. 1939. "Plant Viruses. The Influence of Recent Knowledge on Methods for Their Control." (Reprint 271.)

A general review of the chemical nature of plant viruses is followed by a discussion of the bearing of the facts so presented on the planning of measures to control viral diseases.

The difference between resistance and toleration was emphasized. The possibility of using, for protective inoculation, mild laboratory strains of viruses produced by alteration of specific chemical groups, was suggested, along with other possible lines of attack.

It was pointed out that a biochemical investigation of selected varieties of known differences in respect to susceptibility may result in finding some factor or factors associated with disease resistance which the geneticist could handle in breeding experiments.

R. J. Best. Nature *145*: 627. 1940. "Some Effects of Salicylate on Plant Viruses." (Reprint 285.)

Solutions of K salicylate at pH 7 inactivate the viruses of tobacco mosaic and tomato spotted wilt.

Tobacco mosaic virus is thrown out of its solutions in water as a white, amorphous, granular mass of denatured protein. Parallel with these changes is a loss of infectivity. The rate of inactivation of virus by salicylate varies with concentration of salicylate, and at any concentration above 0·46 M is logarithmic. A curve illustrating the rate of inactivation at 0·7 M K salicylate was included. (Owing to a mistake in transcription the published curve is incorrectly referred to 1·0 M salicylate).

The virus of tomato spotted wilt is inactivated in one hour by 0·1 M salicylate.

R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. *18*: 307. 1940. "The Action of Electrolytes on Solutions of Tobacco Mosaic Virus Nucleoprotein (*Marmor tabaci* var. *vulgare* Holmes)." (Reprint 294.)

The critical concentrations of a number of electrolytes which are necessary to precipitate tobacco mosaic virus from its solutions in water at pH 7 and 30° C. have been determined. The precipitating power of positively charged ions runs parallel with their valency. The virus is precipitated from solution in the form of paracrystalline needles and fibres which return their infectivity and are birefringent.

The nature of the anion has a marked influence on the precipitating power of the salts of a particular cation. The order of effectiveness was $(NO_3)' < (CNS)' < I' < Br' < Cl'$ = succinate = acetate < phthalate < phosphate < oxalate < tartrate < malate < sulphate < citrate; a typical lyotropic series. Under certain conditions the virus readily forms thixotropic gels. Salicylates behave anomalously and denature the virus protein.

R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. *18*: 401. 1940. "Methods for the Preparation of Pure Tobacco Mosaic Virus Nucleoprotein (*Marmor tabaci* var. *vulgare* Holmes)." (Reprint 302.)

The paper summarizes methods developed at the Waite Institute for the preparation of pure samples of tobacco mosaic virus. An important feature is the harvesting of the infected leaves immediately after a period of darkness. This has the effect of making easy the removal of pigments from the preparation. This is also assisted by aerating the juice for 24 hours.

The virus is precipitated from the juice by adding to it an equal volume of 30 per cent. ammonium sulphate. The precipitate is recovered by centrifuging at about 2,000 g., and the virus is recovered from the precipitate by extraction with water. Some impurities are removed from this solution by centrifuging for one hour at 2,000 g. This sequence of operations is repeated several times. Next the virus is precipitated from its aqueous solution by adding an equal volume of acetate buffer solution at pH 3·4. The isoelectrically precipitated virus is collected, redispersed in water, and dissolved by the slow addition of 0·02 N sodium hydroxide solution. After centrifuging to throw out insoluble impurities, the process is repeated until no further purification can be effected.

A method of preparing dried samples of virus for analysis is also described.

V. PLANT NUTRITION AND PLANT PHYSIOLOGY.

A. H. K. Petrie. Aust. Chem. Inst. Jour. & Proc. *6*: 43. 1939. "Protein Synthesis in Plants." (Reprint 253.)

Various hypotheses are discussed for the sequence along which proteins may be synthesized in plants. It is concluded that we cannot yet decide which of these may be correct. Consideration is given to the mechanism controlling protein synthesis in the plant. A relation between the contents of protein nitrogen, amino-nitrogen, and water in leaves is described, and it is concluded that a simple mass action conception is insufficient to account for the amount of protein synthesis. This fact leads to the theory that proteins are maintained in the plant at supra-equilibrium concentrations by a continuous expenditure of energy. Relations of synthesis to respiration rate, oxygen supply, and sugar concentration are discussed.

A. H. K. Petrie, Ruth Watson, and E. Dorothy Ward. Aust. Jour. Exp. Biol. and Med. Sci. *17*: 93. 1939. "Physiological Ontogeny in the Tobacco Plant. 1. The Drifts in Dry Weight and Leaf Area in Relation to Phosphorus Supply and Topping." (Reprint 264.)

This represents the first of a series of papers describing a study of the growth of the tobacco plant. In all parts of the plant, increasing the phosphorus supply to an optimum increased the dry weight, while excess phosphorus supply generally caused depression. Phosphorus deficiency delayed the development of the axis. Topping caused increase in dry weight of the whole plant, especially the roots and leaves. The increased leaf and root growth tended to be the counterpart of the inflorescence development in the untopped plants. Increasing phosphorus supply produced more marked increase in area than in dry weight of leaves. The maximum area was attained earlier than the maximum dry weight. Leaf area was increased by topping, but to a much less extent than dry weight. Consideration is given to the significance of the inflorescence as a determinant of the ontogeny of other organs.

Joan Walkley. New Phytol., *39*: 362. 1940. "Protein Synthesis in Mature and Senescent Leaves of Barley." (Reprint 308.)

Experiments carried out by various workers with detached foliage leaves in nutrient solutions, and with decapitated plants, suggest that the mature leaves of annual plants are unable to synthesize protein. In the present work the fourth leaf of barley was investigated at three different ages after it had reached its maximum area. All the tillers and the main shoot above the ligule of the fourth leaf, which acted as sinks, were removed, and extra nitrogen was supplied to the roots. Under these conditions protein was rapidly synthesized in the leaves. The capacity for synthesis was apparently retained so long as chlorophyll was present, but the rate of synthesis declined with age.

Ruth Watson. Aust. Jour. Exp. Biol. & Med. Sci. *17*: 241. 1939. "Physiological Ontogeny in the Tobacco Plant. 2. The Drifts in Water Content of the Leaves in Relation to Phosphorus Supply and Topping." (Reprint 272.)

Absolute water content was increased with high phosphorus supply to a relatively greater extent than the dry weight; that is, treatment increased the percentage water content. Senescent fall in absolute water content, however, tended to be greater with higher phosphorus treatment; this is attributed to relative nitrogen deficiency in the plants receiving high phosphorus supplies. Topping increased the absolute water content, but to a relatively less extent than the dry weight, so that in general it decreased the percentage water content. It is concluded that assimilates in the upper leaves of the topped plants, which normally would have been translocated to the inflorescence, were partly accumulated as reserve materials or as mechanical tissue. There was a marked correlation between leaf area and absolute water content.

E. Dorothy Ward and A. H. K. Petrie. Aust. Jour. Exp. Biol. & Med. Sci. *18*: 21. 1940. "Physiological Ontogeny in the Tobacco Plant. 3. The Drifts in Organic-acid Content of the Leaves in Relation to Phosphorus Supply and Topping." (Reprint 279.)

The absolute total organic acidity increased up to the time of attainment of maturity of the leaves. Thereafter there was a further increase in oxalic acid, most marked in the upper leaves. The acidity due to the remaining acids underwent no further appreciable increase after maturity. The percentage organic acidity tended to remain constant or to fall until maturity; thereafter it fell so long as the dry weight increased, and then rose when the dry weight began to fall. Increasing phosphorus supply depressed the percentage organic acidity on a dry-weight basis, and the data suggest that this applied also to the concentration of organic acids in the cell sap. Topping caused a decrease in percentage total organic acidity and oxalic-acid content of the lower and middle leaves; this is attributable to the increased accumulation of reserve materials. In the upper leaves topping caused a great accumulation of oxalic acid, so that the percentage was increased, and the tendency for accumulation of reserve materials to depress the percentage total organic acidity in these leaves was obscured.

Ruth Watson and A. H. K. Petrie. Aust. Jour. Exp. Biol. & Med. Sci. *18*: 313. 1940. "Physiological Ontogeny in the Tobacco Plant. 4. The Drift in Nitrogen Content of the Parts in Relation to Phosphorus Supply and Topping, with an Analysis of the Determination of Ontogenetic Changes." (Reprint 293.)

The maximum absolute nitrogen content of the total plant was slightly increased with increasing phosphorus treatment, but was unaffected by topping. The absolute nitrogen content was at first greater with high phosphorus supply in all parts, but in the vegetative parts of the untopped plants and the lower parts of the topped plants it was ultimately greater with low phosphorus supply. Both topping and phosphorus deficiency delayed migration of nitrogen from the leaves during senescence. The percentage nitrogen in all parts was at first high with high phosphorus supply, but subsequently it became lower. An analysis is presented of the determination of the ontogenetic changes observed throughout the investigation. Dry-weight and leaf-area changes are considered in relation to four growth processes and their determinants: the processes are cell division, cell extension, accumulation of reserves, and differentiation causing cessation of cell-wall extension. The major determinants of nitrogen uptake by the plant are regarded as the declining external concentration, the capacity of the various parts as sinks, and the redistribution of nitrogen within the plant during the growing period. Increased rate of protein synthesis with increased phosphorus supply probably accounted for the greater intake of nitrogen by the various organs with higher treatment.

R. F. Williams. Aust. Jour. Exp. Biol. & Med. Sci. *17*: 123. 1939. "Physiological Ontogeny in Plants and its Relation to Nutrition. 6. Analysis of the Unit Leaf Rate." (Reprint 265.)

The unit leaf rates (net assimilation rates) previously obtained in four experiments with wheat, Sudan grass, and oats are analysed. One of the important factors causing the characteristic decline in this rate is the progressive decrease in the cytoplasm content of the leaves with time. Since the best available measure of this content is the protein content, net assimilation rate has been expressed on a protein basis. The latter rate was found to be closely related to drifts in certain climatic factors, notably temperature. This relation was obscured when the rate was expressed on a dry-weight basis. Certain effects of the varying nutrient supplies on net assimilation rate (protein basis) are discussed in relation to the nitrogen status of the respective plants.

VI. FIELD CROPS AND PASTURES.

C. M. Donald. Jour. C.S.I.R. *12*: 212. 1939. "Strain Variation in *Bromus unioloides*. H. B. *et* K. (Prairie Grass)." (Reprint 274.)

Eight genetically stable types were recognized as a result of observations on approximately seven thousand single plants of *Bromus unioloides*. Five types were found to be completely susceptible, and three types completely immune to prairie grass smut (*Ustilago bromivora*). Field infection of susceptible types was effectively prevented by mercurial dusts.

One type immune to smut infection gave outstanding results. This type was shown to be considerably more productive and more persistent than the commercial type in common use.

R. E. Shapter. Jour. C.S.I.R. *12*: 23. 1939. "An Experiment to Detect the Possible Excretion of Nitrogen by Leguminous Plants." (Reprint 257.)

An experiment was carried out which was designed to determine directly whether soluble nitrogenous compounds accumulate in the medium external to the roots of growing leguminous plants. Lucerne was grown in pure quartz sand, freed from all finely divided extraneous matter, supplied with a nitrogen-free culture solution, and inoculated with a culture of *Rhizobium meliloti* which had been found especially effective on lucerne. The apparatus was constructed so that the culture solution could be drawn off at intervals from the bottoms of the pots, the sand leached, and fresh culture solution added. The roots thus remained in their natural condition, undisturbed and unbroken. The nitrogen content of the liquors drawn off was then determined. The quantities of nitrogen found, which in general tended to increase in the later leachings, were so small as to be of little significance. The method employed did not bring forward any positive evidence to establish the excretion of nitrogenous compounds from the roots of leguminous plants.

T. H. Strong. Jour. Aust. Inst. Agric. Sci. *6*: 14. 1940. "Non-effective Associations of Nodule Bacteria and Legumes." (Reprint 282.)

From the experimental evidence which has been obtained during the past few years it is concluded that the host plant is of primary importance in determining whether the association is effective or non-effective. None of the strains so far isolated at the Waite Institute has proved to be parasitic in the absolute sense. Strains of *Rhizobium leguminosarum*, for example, non-effective with the tick beam, have proved to be effective in association with the field pea. Strains of *Rhizobium meliloti*, non-effective with King Island melilot, have proved effective with lucerne.

Various tests were carried out where non-effective and effective strains were introduced at the same time and at various intervals to pots growing the host plant, and in most cases the yields of total nitrogen have not been greatly lowered. The various types of association of organism and host plant are discussed, with particular reference to the influence of soil factors on the effectiveness of the association.

H. C. Trumble. Jour. Agric. Sth. Aust. *42*: 953. 1939. "Barrel Medic (*Medicago tribuloides*, Desr.) as a Pasture Legume." (Reprint 263.)

Attention is drawn to the value of *Medicago tribuloides* as a constituent of temporary and permanent pastures. The agronomic features of this species are compared with those of allied *Medicago* spp. Barrel medic has found an important place as an annual legume on soils high in available lime which do not grow subterranean clover satisfactorily.

D. C. Wark and L. J. Cook. Dept. Agric. Sth. Aust. Bull. 340. 1939. "The Relationship of Nitrogeneous Fertilizers to Stubble-sown Cereal Crops in South Australia." (Reprint 254.)

From fertilizer trials with cereals on stubble or other non-fallow land at country centres, it was found that the yield of a stubble crop without nitrogenous fertilizers, and the response to sulphate of ammonia, both tended to increase with increasing May–October rainfall. The response to sulphate of ammonia tended to be greatest where the nitrate content of the soil was low. Neither the May–October rainfall, nor the soil nitrate at seeding, alone or in combination, could be used to predict the response to sulphate of ammonia.

Nitrate content of a stubble soil was associated with the soil type rather than with the known history of the land. Where the rotation had recently included pasture higher yields were obtained than where the land had been almost entirely devoted to cereal growing. The responses to sulphate of ammonia were, if anything, slightly larger where pasture had been included in the rotation.

VII. DISEASES OF PLANTS.

D. B. Adam. Jour. Aust. Inst. Agric. Sci. *6*: 48. 1940. "On the Occurrence of *Cercosporella Herpotrichioides*, Fron. in South Australia." (Reprint 284.)

This fungus, which causes "eyespot lodging" disease of wheat, was found for the first time in South Australia on some heavily cropped plots at the Waite Institute. Some characteristics of the fungus itself, and the disease symptoms which it promotes on wheat, are described. Reference is made to the relation of the development of this disease to soil type and rainfall in other parts of the world, and the bearing of this information on the present limited outbreaks.

T. T. Colquhoun. Jour. Agric. Sth. Aust. *42*: 704. 1939. "Seed Pickling." (Reprint 259.)

A résumé of the development of seed treatments for the prevention of seed-borne diseases in crops is followed by a discussion on the merits of various methods in common use. Heat treatments and the use of chemicals, either in solution or dust form, are briefly described. A table of suggested treatment for seed of various crops is included.

T. T. Colquhoun. Jour. Aust. Inst. Agric. Sci. *6*: 54. 1940. "Effect of Manganese on Powdery Mildew of Wheat." (Reprint 281.)

Wheat plants were grown in quartz sand to which was added culture solution free from manganese. Four groups of plants were treated with manganese sulphate at the following levels (in lb. per ac.) 0, 16, 32, and 264. Each addition of manganese sulphate significantly reduced the infection by powdery mildew below that of the preceding smaller dressing.

A. T. Pugsley. Jour. Aust. Inst. Agric. Sci. *6*: 195. 1940. "Transmutation of Bacterial Plant Pathogens." (Reprint 303.)

The reprint is an account of the recent work of Harris, Naghski, Farrell, and Reid, who were able to secure the pathogen *Phytomonas tabaci* from rough cultures of the soil-inhabiting bacterium *Pseudomonas fluorescens*.

The bearing of this work on the general problem of the parasitism of bacterial plant pathogens is discussed.

VIII. INVESTIGATIONS ON ECONOMIC INSECTS.

H. G. Andrewartha. Jour. Agric. Sth. Aust. *43*: 99. 1939. "The Small Plague Grasshopper (*Austroicetes cruciata* Sauss.)." (Reprint 270.)

The distribution in South Australia of *Austroicetes cruciata* is illustrated by a map. The paper gives a brief summary of the life history and habits of the grasshopper. Control measures are reviewed.

H. G. Andrewartha. Trans. Roy. Soc. Sth. Aust. *64*: 76. 1940. "The Environment of the Australian Plague Locust (*Chortoicetes terminifera* Walk.)." (Reprint 288.)

Field observations have shown that *Chortoicetes terminifera* occurs as a solitary grasshopper over most of South Australia. The character of the winter inhibits the development of swarms in the agricultural areas. The "outbreak areas" are situated further north in the semi-arid pastoral districts. The distribution of favourable habitats for the grasshopper is associated with vegetation and soil. There is considerable evidence that favourable weather for several successive seasons is necessary before a major outbreak can occur. There are nine diagrams and maps. Vegetation types are illustrated by six photographs.

D. C. Swan. Jour. Agric. Sth. Aust. *43*: 462. 1940. "The Lucerne Flea (*Smynthurus viridis* L.)" (Reprint 280.)

A summary is given of present knowledge of the biology of this insect, and of its economic significance as a pest of pastures and market crops in South Australia. The effects of weather and of natural enemies on its fluctuations in numbers in the field are discussed. Recommendations are made for controlling it, both by cultural methods and by spraying.

IX. CLIMATOLOGY.

J. A. Prescott. Trans. Roy. Soc. Sth. Aust. *64*: 114. 1940. "Evaporation from a Water Surface in Relation to Solar Radiation." (Reprint 289.)

When the saturation deficit of atmospheric vapour pressure is sufficiently high the evaporation from a free water surface tends to be limited by the net radiation falling on the water surface. The relationship between measured evaporation, measured saturation deficit, and estimated solar radiation for Canberra has been examined. The solar radiation was estimated from the observed radiation at Mt. Stromlo, and the hours of sunshine at Canberra.

The most useful equation connecting these observations takes the form:

$$\log\left(1-\frac{E}{Q}\right) = -0{\cdot}033\ \text{s.d.} - 0{\cdot}065$$

where E is the evaporation expressed in gramme calories of latent heat, Q is the solar radiation, and s.d. is the saturation deficit expressed in millibars.

H. C. Trumble. Trans. Roy. Soc. Sth. Aust. *63*: 36. 1939. "Climatic Factors in Relation to the Agricultural Regions of Southern Australia." (Reprint 266.)

Methods previously employed (Trumble, 1937) as a basis for the climatic classification of the agricultural areas of South Australia are reviewed in the light of further evidence, and extended to embrace the agricultural areas of southern Australia generally.

A map showing agroclimatic zones for southern Australia, based on the mean length of the rainfall season and mean winter temperatures, is included. The importance of further work to investigate the variability of single value measures within each defined zone is stressed.

X. STATISTICAL METHOD.

E. A. Cornish. Jour. Aust. Inst. Agric. Sci. *6*: 31. 1940. "The Analysis of Quasi-Factorial Designs with Incomplete Data." (Reprint 283.)

This is the first of a series of papers concerned with methods of analysing data derived from quasi-factorial designs in which complete sets of experimental values are missing. The paper deals with balanced incomplete blocks and Youden squares, and considers in detail the cases of a missing block and a missing treatment.

E. A. Cornish. Annals of Eugenics *10*: 112. 1940. "The Estimation of Missing Values in Incomplete Randomized Block Experiments." (Reprint 291.)

The procedure for supplying a missing value in a table of experimental results, so that efficient and unbiased estimates of treatment effects may be derived, is here extended to incomplete randomized block and Youden square designs. The formulae provide estimates which utilize only the intra-block information on the treatment comparisons. The exact analysis of variance and the errors of treatment comparisons are briefly discussed.

E. A. Cornish. Annals of Eugenics *10*: 137. 1940. "The Estimation of Missing Values in Quasi-Factorial Designs." (Reprint 297.)

The procedure for estimating missing values is extended to quasi-factorial designs generally. The estimation of several missing values, the exact analysis of variance, and the errors of treatment comparisons are briefly discussed.

E. A. Cornish. Annals of Eugenics *10*: 269. 1940. "The Analysis of Covariance in Quasi-Factorial Designs." (Reprint 300.)

The extension of covariance analysis to quasi-factorial designs in general is discussed from the standpoint of the utilization of intra-block information, and illustrated by numerical examples.

XI. MISCELLANEOUS.

J. A. Prescott. Proc. Roy. Geog. Soc. (S.A. Branch), Session 1937–38: 52. "The Agricultural Possibilities of Monsoonal Australia." (Reprint 261.)

Consideration is given to the climatic factors and major soil features likely to control agricultural development in the northern parts of Australia which are subject to marked

seasonal rainfall. The most important climatic influences are the length of the season, and the reliability of the summer rains. A substantial proportion of the area is covered by ranges and tablelands with shallow, stony soils not suitable for agriculture.

Comparison with West Africa suggests a number of possible annual crops suited to these conditions. Suitable grain crops, legumes, and tubers are listed.

The present state of settlement is briefly outlined.

J. K. Taylor. Jour. Aust. Inst. Agric. Sci. *6*: 78. 1940. "America's New Deal in Agriculture." (Reprint 287.)

The paper is a brief discussion of the economic conditions of American agriculture and the factors affecting it in the period after the World War 1914–1918. The New Deal may be summed up briefly as stability and security: a policy to save the farmer and the soil. The decline of American farming over the past ten years has necessitated a strong Government policy. Some of the organizations developed, and their methods of approach to the various problems involved are described.

H. C. Trumble. Jour. Aust. Inst. Agric. Sci. *5*: 38. 1939. "Survey of Rural Potentialities in Relation to Population Capacity. 1. The Determination of Agricultural and Pastoral Resources in South Australia." (Reprint 258.)

This paper describes the results of an enquiry undertaken by the Agricultural Science Club of the Waite Institute to assess in a preliminary way the extent to which agricultural and pastoral production could be increased in South Australia. A factual basis was provided by production surveys, the analysis of edapho-climatic zones, and the results of field investigation relating to crop and pasture production. It was estimated that 2·8 times the existing population could be maintained, at existing standards, on the primary resources of South Australia.

Records of Field Experimental Work

LIST OF FIELD EXPERIMENT RECORDS.

1. Permanent Rotation Experiment, 1925–40.
2. Influence of Grazed and Harvested Forage Crops on the Yield of Temporary Pasture and Wheat in Four-Course Rotations.
3. Effect of Superphosphate, Nitrogen, and Lime on the Yield of Wheat, Oats, Barley, and Peas in Four-Course Rotations.
4. Effect of Time of Sowing, Seed Rate, and Superphosphate on the Yield of Flax, 1939.
5. Effect of Time of Sowing and Seed Rate on the Yield of Flax, 1940.
6. Effect of Time of Sowing and Seed Rate on the Yield of Flax, 1937–40.
7. Variety Trial with Linseed, 1940.
8. Influence of Top-Dressing on the Yield of Natural Pasture.
9. Effect of Nitrogen as Sulphate of Ammonia on the Yield of a Seeded Permanent Pasture under Different Systems of Management.
10. Effect of Superphosphate and Surface Cultivation on the Yield and Botanical Composition of a Seeded Pasture.
11. Effect of Differential Grazing Management on the Yield and Botanical Composition of a Seeded Pasture.
12. Grazing Value of Top-Dressed Natural and Seeded Pastures at Kybybolite.
13. Establishment and Yield of Cereal Crops and Herbage Plants on a Sand Drift at Pallamana.

A NOTE ON THE CONSTRUCTION AND USE OF THE SUMMARY TABLES.

Mean yield of seed in bushels per ac. Mean of all phosphate ± 0·358.

	Seed rate: lb. per ac.				Mean.	Diff.
Time of sowing.	20	40	60	80	± 0·418	± 0·591
E	9·30	13·38	12·84	13·28	**12·20**	—
L	3·19	5·41	6·19	6·47	**5·31**	*— 6·89*
Mean ± 0·253	**6·25**	**9·39**	**9·52**	**9·87**	**8·76**	—
Difference ± 0·358	—	*+ 3·14*	*+ 0·13*	*+ 0·35*	—	—

In this table and others of similar construction, the numbers in ordinary type are the mean yields of the treatments indicated at the headings of the columns and the left-hand margins of the rows. Thus 9·30 is the yield of seed in lb. per ac. averaged over all phosphate treatments and all plots sown early at 20 lb. per ac. The numbers in heavy type denote more general averages. Thus 12·20 is the yield in bushels per ac. averaged over all phosphate treatments and all seed rates of the plots sown early. The general mean of all treatments is 8·76 bushels per ac.

The standard errors (prefaced by the sign ±) applicable to all comparisons of likely interest are included in the tables. As a general rule, it may be taken that a quantity is significant if it exceeds twice its standard error. Thus the mean decrease in yield as a result of late sowing, 6·89 ± 0·591, is definitely significant. The average increase due to a seed rate of 80 lb. per ac. over that of 60 lb. per ac., 0·35 ± 0·358, is not significant.

In testing the difference between two quantities having the same standard error, it may be assumed that the difference is significant if it exceeds three times that standard error. Thus the difference between 9·30 and 13·38 is 4·08, and since this exceeds three times 0·358 there is a significant increase in yield due to the higher seed rate when the crop is sown early.

The areas of plots given in the tables denote areas at harvest. Unless otherwise specified, the experiments have been conducted at the Waite Institute.

1. PERMANENT ROTATION EXPERIMENT, 1925–40.

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per ac.:

Sepoy wheat, 90 lb.; Early Burt oats, 70 lb.; Pryor barley, 80 lb. White Brunswick peas, 150 lb.; Wimmera rye-grass, 15 lb.; Sudan grass, 15 lb.

Basal dressing of 94 lb. per ac. superphosphate 1925–28, 187 lb. per ac. 1929–40.

Design: 31 plots, grouped in 12 rotations, so that each course of the 12 rotations is represented every year. Rotations as per table.

Area of each plot = 1/7th acre.

(Grain yields in bushels per ac., Wimmera rye-grass in cwt. dry matter, and Sudan grass in cwt. green fodder per ac.)

Rotation.	Crop.	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1933.	1934.	1935.	1936.	1937.	1938.	1939.	1940.	Mean. 1926–40
1	Fallow																	
	Wheat	36·64	44·10	35·40	30·39	48·88	42·35	21·41	24·79	39·78	45·73	20·88	37·51	31·56	28·22	32·96	35·18	34·61
2	Peas	11·10	16·40	2·50	21·58	20·82	18·84	14·70	34·01	27·74	12·48	6·70	17·15	26·25	9·72	32·83	16·32	18·54
	Wheat	39·45*	43·70	37·00	26·71	38·97	42·47	18·78	23·83	25·32	23·33	10·22	17·03	30·45	26·67	21·72	19·73	27·06
3	Fallow																	
	Wheat	39·86	39·60	39·60	28·11	50·87	46·08	23·01	36·31	44·48	47·77	33·92	46·72	37·33	33·25	39·47	37·75	38·95
	Rye-grass	42·36	48·88	Grazed	55·12	31·50	30·68	17·81	32·24	10·22	17·63	2·20	7·31	17·46	26·71	38·64	24·80	25·80
4	Fallow																	
	Wheat	36·72	39·80	39·70	28·46	49·82	43·87	24·56	27·77	44·77	52·85	24·88	40·72	41·59	31·49	28·45	36·63	37·02
	Oats	80·10	67·30	53·10	71·75	75·34	68·42	46·29	60·64	35·44	46·55	1·35	25·29	38·85	37·72	49·53	34·48	47·47
5	Fallow																	
	Wheat	36·79	38·40	39·60	28·46	52·09	39·78	24·99	33·31	45·67	56·17	33·65	47·83	41·30	34·60	40·45	37·71	39·60
	Peas	10·66	16·90	4·10	31·15	22·40	32·66	26·77	50·98	32·61	27·12	17·01	25·20	28·93	13·91	34·07	19·05	25·52
6	Fallow																	
	Wheat	33·51	39·30	41·00	29·75	53·90	38·03	26·10	33·31	45·12	50·87	24·55	48·94	41·88	36·70	38·16	39·67	39·15
	Barley	83·65	68·80	55·30	69·44	59·50	63·10	51·10	53·62	25·41	37·52	33·39	28·35	51·17	40·63	55·20	25·38	47·86
7	Wheat	37·23	22·60	30·00	26·71	27·12	18·26	12·98	12·72	8·92	9·57	1·43	8·46	23·92	11·33	9·27	10·04	15·56
8	Peas	11·90	16·70	4·10	31·79	25·90	22·40	26·48	46·31	27·01	26·89	26·25	29·52	30·92	22·22	43·12	20·76	26·69
	Wheat	40·00	48·60	44·70	26·54	41·47	44·10	20·97	29·66	32·32	28·82	10·13	19·13	36·98	32·24	21·43	30·14	31·15
	Oats	89·02	68·20	54·20	65·80	57·35	64·75	31·02	35·26	25·16	25·90	28·49	19·51	41·47	6·86	45·58	25·24	39·65
9	Peas	11·90	18·70	4·10	31·85	27·36	25·14	29·63	42·41	26·25	28·23	24·91	28·35	31·44	25·65	44·32	19·71	27·20
	Wheat	37·23	45·00	44·30	27·65	44·45	44·04	22·11	35·06	33·37	30·45	13·85	24·50	38·50	33·18	29·15	31·12	33·12
	Barley	89·95	64·30	61·70	69·16	61·18	62·65	40·78	38·57	27·54	38·36	20·43	36·05	53·06	38·12	54·33	23·28	45·97
10	Fallow																	
	Wheat	44·68	42·80	46·90	30·74	56·82	48·18	31·27	37·42	49·52	58·16	42·00	55·53	45·91	37·44	44·89	44·23	44·79
	Oats	85·08	66·06	47·80	64·92	78·40	80·67	55·56	72·41	40·69	48·69	42·92	36·84	59·50	46·63	75·34	40·75	57·15
	Rye-grass	48·83	48·06	Grazed	59·50	37·62	34·50	27·62	39·80	12·26	12·69	15·88	8·78	18·72	24·48	37·10	30·55	29·11
11	Sudan grass	9·45	17·26	12·21	2·68	34·12	52·50	3·91	—	—	—	0·24	15·75	121·37	13·95	54·08	40·95	24·60
	Wheat	42·92	40·70	45·80	29·05	45·21	44·62	32·93	33·10	27·88	39·17	28·38	23·16	40·72	20·48	44·86	16·19	34·15
12	Fallow																	
	Wheat	41·90	39·70	43·00	28·64	53·84	46·55	26·54	28·12	42·35	46·08	34·94	38·50	40·77	29·36	41·37	30·68	38·03

* Estimated.

2. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS.

Rotations:

A	B	C	D	E
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

Variety of crop and seed rate per ac.:

Sepoy wheat, 90 lb.; Cape barley, 80 lb.; Mulga Oats, 70 lb.; White Brunswick peas, 150 lb.; Clover mixture (Mt. Barker subterranean clover, Dwalganup subterranean clover, and barrel medic), 10 lb. per ac. of each; Wimmera rye-grass, 10 lb. per ac. as pasture.

Basal fertilizer dressing: 2 cwt. superphosphate per acre to all crops, including pasture.

Forage crop treatment: G = grazed. H = harvested.

Design: 60 main plots in 4 groups of 15 plots, each representing one course of the rotation. The groups of 15 plots are divided into 3 randomized blocks of 5 plots, each representing a different rotation. Each plot is subdivided into halves: on one the forage crop is grazed, and on the other it is harvested.

Area of main plots = $\frac{1}{6 \cdot 94}$ acre.

(a) Yields of forage crops.

	A After peas.			B After clover.		C After barley.			D After oats.		
	G	H		G	H	G	H		G	H	
Year.	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)
1937	55·37	49·89	39·83	25·07	24·11	17·92	19·80	21·10	15·84	20·11	23·38
1938	42·09	41·67	23·53	16·98	10·27	26·35	29·82	28·73	13·22	25·62	31·92
1939	49·54	49·47	40·74	48·57	44·63	27·97	38·19	41·77	38·17	37·24	38·84
1940	41·67	30·65	25·50	8·16	8·09	15·17	14·62	15·66	16·91	15·73	22·26
Mean	**47·17**	**42·92**	**32·40**	**24·69**	**21·77**	**21·85**	**25·61**	**26·81**	**21·03**	**24·67**	**29·10**

(b) Yields of temporary pasture in cwt. per ac.

	A		B		C		D	
Year.	G	H	G	H	G	H	G	H
1937	33·23*		19·28*		19·41*		18·14*	
1938	30·05	20·67	22·77	19·30	13·66	8·41	11·18	8·44
1939	58·90	46·37	24·59	23·25	23·23	13·91	21·78	13·63
1940	36·09	23·79	26·53	16·87	18·86	8·32	12·26	5·78
Mean	**41·68**	**30·28**	**24·63**	**19·81**	**18·58**	**10·21**	**15·07**	**9·28**

* Forage crops were not differentially treated in 1936.

(c) Yields of wheat in bushels per ac.

	A After peas.		B After clover.		C After barley.		D After oats.		E After fallow-wheat.	
Year.	G	H	G	H	G	H	G	H	G	H
1937	43·75	43·71	37·17	39·39	40·16	39·93	38·66	43·15	40·01	39·26
1938	39·64	42·01	37·71	39·49	39·68	40·99	37·54	39·89	30·51	32·20
1939	49·56	50·68	48·14	45·19	46·08	45·11	45·67	44·27	38·56	38·19
1940	48·95	47·91	51·69	49·20	51·67	49·30	50·53	47·62	50·72	47·47
Mean	**45·47**	**46·08**	**43·68**	**43·32**	**44·40**	**43·83**	**43·10**	**43·73**	**39·95**	**39·28**

No statistical analyses have yet been carried out on the data from this experiment.

3. EFFECT OF SUPERPHOSPHATE, NITROGEN, AND LIME ON THE YIELD OF WHEAT, OATS, BARLEY, AND PEAS IN FOUR-COURSE ROTATIONS.

Rotations:

A	B	C	D
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

Variety of crop and seed rate per ac.:

Seewari wheat, 90 lb.; Mulga oats, 70 lb.; Pryor barley, 80 lb.; White Brunswick peas, 150 lb. Pasture: Wimmera rye-grass, 3 lb. + Mt. Barker subterranean clover, 6 lb. + Dwalganup subterranean clover, 6 lb.

Fertilizer treatments:

Superphosphate: P_0 = nil, P_1 = 1 cwt. per ac., P_2 = 2 cwt. per ac.
Sulphate of ammonia: N_0 = nil, N_1 = 1 cwt. per ac., N_2 = 2 cwt. per ac.
Lime (calcium hydroxide): L_0 = nil, L_1 = 2½ cwt. per ac., L_2 = 5 cwt. per ac.
All combinations of superphosphate, sulphate of ammonia, and lime are applied to the cereal crops and peas. The pastures receive no fertilizer.

Design: 432 plots, in 4 groups of 108 plots, one group to each rotation. Each of these groups of 108 plots is subdivided into 4 sections of 27 plots, and these sections represent the four courses of each rotation in every year. Each section of 27 plots is subdivided into 3 randomized blocks of 9 plots for the application of the fertilizer treatments. This subdivision confounds a pair of degrees of freedom for second order interaction with soil differences.

Area of a single plot = 1/77th acre.

Yields of grain in bushels per ac.

Rotation A.

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
					Wheat, 1939.						
P_0	39·25	38·71	39·03	37·11	40·32	39·57	**39·00**	L_0	44·38	41·92	41·71
P_1	47·91	47·27	44·81	45·56	45·88	48·55	**46·66**	L_1	44·27	44·38	42·56
P_2	44·81	44·81	44·70	45·34	45·02	43·95	**44·77**	L_2	43·31	44·49	44·27
Mean	**43·99**	**43·60**	**42·85**	**42·67**	**43·74**	**44·02**	**43·44**				
					Wheat, 1940.						
P_0	47·27	45·88	46·73	47·91	47·05	44·92	**46·63**	L_0	46·73	43·74	42·67
P_1	45·34	43·95	42·24	45·02	42·78	43·74	**43·85**	L_1	44·59	44·27	43·52
P_2	41·92	43·10	39·89	40·21	42·56	42·13	**41·63**	L_2	43·20	44·91	42·67
Mean	**44·84**	**44·31**	**42·95**	**44·38**	**44·13**	**43·60**	**44·04**				
					Wheat, 1937–40.						
P_0	43·48	43·99	42·89	42·58	44·35	43·42	**43·45**	L_0	45·27	44·23	43·19
P_1	47·02	45·95	43·99	45·10	44·66	47·20	**45·65**	L_1	45·18	45·04	43·73
P_2	45·31	45·23	43·92	45·00	44·94	44·51	**44·82**	L_2	45·36	45·89	43·88
Mean	**45·27**	**45·05**	**43·60**	**44·23**	**44·65**	**45·04**	**44·64**				
					Peas, 1939.						
P_0	34·33	36·14	30·91	36·25	32·30	32·83	**33·79**	L_0	35·83	36·04	30·48
P_1	37·11	34·11	31·01	31·01	33·15	38·07	**34·08**	L_1	34·54	33·47	30·48
P_2	35·93	32·94	31·44	35·08	33·04	32·19	**33·44**	L_2	37·00	33·69	32·40
Mean	**35·79**	**34·40**	**31·12**	**34·11**	**32·83**	**34·36**	**33·77**				

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
					Peas, 1940.						
P_0	28·77	30·58	33·58	27·80	32·19	32·94	**30·98**	L_0	32·19	33·15	32·94
P_1	37·22	36·79	36·04	36·47	36·04	37·54	**36·68**	L_1	33·05	34·22	37·00
P_2	35·29	35·61	37·21	34·01	36·04	38·07	**36·04**	L_2	36·04	35·61	36·89
Mean	**33·76**	**34·33**	**35·61**	**32·76**	**34·76**	**36·18**	**34·57**				
					Peas, 1937–40.						
P_0	29·37	30·12	30·34	30·29	30·10	29·44	**29·94**	L_0	33·26	32·98	30·26
P_1	34·44	33·36	31·40	32·65	32·93	33·63	**33·07**	L_1	32·09	31·51	32·18
P_2	34·98	32·59	32·45	33·56	32·75	33·70	**33·34**	L_2	33·44	31·58	31·75
Mean	**32·93**	**32·02**	**31·40**	**32·17**	**31·93**	**32·26**	**32·12**				
					Rotation B.						
					Wheat, 1939.						
P_0	28·45	27·06	30·48	28·45	27·91	29·62	**28·66**	L_0	33·90	33·15	34·44
P_1	34·00	34·01	40·64	35·93	37·32	35·40	**36·22**	L_1	29·84	33·37	38·07
P_2	33·15	36·47	37·65	37·11	36·04	34·11	**35·75**	L_2	31·87	31·01	36·25
Mean	**31·87**	**32·51**	**36·25**	**33·83**	**33·76**	**33·04**	**33·54**				
					Wheat, 1940.						
P_0	41·28	39·68	42·67	40·21	41·18	42·24	**41·21**	L_0	42·24	42·78	43·63
P_1	44·06	46·74	43·74	44·49	44·60	45·45	**44·85**	L_1	44·38	42·67	42·89
P_2	45·02	43·96	44·27	43·95	44·17	45·13	**44·42**	L_2	43·74	44·92	44·17
Mean	**43·46**	**43·46**	**43·56**	**42·89**	**43·32**	**44·27**	**43·49**				
					Wheat, 1936–40.						
P_0	34·73	34·36	36·02	34·24	34·55	36·32	**35·04**	L_0	38·07	39·17	39·04
P_1	39·82	40·56	42·65	41·05	40·51	41·47	**41·01**	L_1	38·23	38·05	40·58
P_2	40·15	42·04	42·25	40·99	41·80	41·66	**41·48**	L_2	38·39	39·74	41·32
Mean	**38·23**	**38·99**	**40·31**	**38·76**	**38·95**	**39·82**	**39·18**				
					Oats, 1939.						
P_0	63·04	71·55	73·95	65·77	71·38	71·39	**69·51**	L_0	66·25	79·41	85·98
P_1	67·21	79·09	91·92	86·30	72·03	79·89	**79·41**	L_1	63·20	75·07	82·94
P_2	62·08	78·28	93·20	79·56	77·80	76·20	**77·85**	L_2	62·89	74·43	90·15
Mean	**64·11**	**76·30**	**86·36**	**77·21**	**73·74**	**75·82**	**75·59**				
					Oats, 1940.						
P_0	44·11	56·15	62·24	55·66	52·78	54·06	**54·17**	L_0	44·91	59·20	68·66
P_1	43·15	58·39	65·13	58·39	54·06	54·22	**55·56**	L_1	40·75	58·87	62·08
P_2	41·87	61·12	66·25	58·71	54·86	55·66	**56·41**	L_2	43·47	57·59	62·88
Mean	**43·04**	**58·55**	**64·54**	**57·59**	**53·90**	**54·65**	**55·38**				
					Oats, 1936–40.						
P_0	53·72	64·23	71·74	63·87	63·17	62·65	**63·23**	L_0	55·89	67·54	78·78
P_1	56·48	68·10	78·51	69·75	65·98	67·36	**67·70**	L_1	55·57	66·09	74·43
P_2	55·63	68·74	78·02	68·58	66·94	66·88	**67·46**	L_2	54·38	67·44	75·06
Mean	**55·28**	**67·02**	**76·09**	**67·40**	**65·36**	**65·63**	**66·13**				
					Rotation C.						
					Wheat, 1939.						
P_0	22·46	23·21	24·92	22·14	23·95	24·49	**23·53**	L_0	24·38	28·77	29·19
P_1	30·80	31·66	33·37	29·62	32·51	33·69	**31·94**	L_1	27·91	30·16	31·87
P_2	28·55	34·43	35·50	30·58	33·47	34·43	**32·83**	L_2	29·52	30·37	32·72
Mean	**27·27**	**29·77**	**31·26**	**27·45**	**29·98**	**30·87**	**29·43**				

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
					Wheat, 1940.						
P_0	34·01	37·32	39·78	39·35	35·08	36·68	37·04	L_0	42·35	38·92	40·85
P_1	44·81	34·54	40·53	40·53	40·00	39·35	39·96	L_1	39·68	37·96	36·57
P_2	43·42	39·46	37·75	42·24	39·14	39·25	40·21	L_2	40·21	34·43	40·64
Mean	40·74	37·11	39·36	40·71	38·07	38·43	39·07				
					Wheat, 1936–40.						
P_0	29·54	30·67	31·64	30·24	30·98	30·63	30·62	L_0	35·47	35·63	35·89
P_1	38·66	38·12	38·66	37·70	38·27	39·47	38·48	L_1	35·43	36·92	36·33
P_2	39·26	40·86	39·76	39·05	39·42	41·40	39·96	L_2	36·56	37·09	37·84
Mean	35·82	36·55	36·69	35·66	36·23	37·16	36·35				
					Barley, 1939.						
P_0	49·28	46·45	56·59	47·22	50·43	54·67	50·77	L_0	46·97	53·64	59·16
P_1	45·43	63·26	61·72	53·77	53·51	63·14	56·80	L_1	50·56	53·77	58·77
P_2	52·49	59·93	63·91	58·77	59·16	58·39	58·77	L_2	49·66	62·24	64·29
Mean	49·06	56·55	60·74	53·25	54·37	58·73	55·45				
					Barley, 1940.						
P_0	32·72	37·73	39·91	35·16	38·63	36·57	36·79	L_0	29·51	41·45	44·91
P_1	34·14	45·94	47·74	42·22	42·86	42·73	42·60	L_1	33·37	42·73	47·35
P_2	29·00	41·96	46·20	38·50	41·96	36·70	39·05	L_2	32·98	41·45	41·58
Mean	31·95	41·88	44·61	38·63	41·15	38·67	39·48				
					Barley, 1936–40.						
P_0	40·94	45·70	50·09	44·96	46·56	45·22	45·58	L_0	41·79	48·40	53·80
P_1	42·61	51·98	55·19	49·12	49·43	51·22	49·93	L_1	43·13	49·79	54·70
P_2	43·59	50·75	55·72	49·91	51·62	48·52	50·02	L_2	42·22	50·24	52·51
Mean	42·38	49·48	53·67	48·00	49·20	48·32	48·51				
					Rotation D.						
					Wheat, 1939.						
P_0	31·55	31·55	29·09	30·37	30·16	31·65	30·73	L_0	37·32	36·36	34·97
P_1	37·21	38·82	40·64	38·71	39·03	38·92	38·89	L_1	36·25	36·68	36·57
P_2	39·57	40·42	39·68	39·57	40·31	39·78	39·89	L_2	34·75	37·75	37·86
Mean	36·11	36·93	36·47	36·22	36·50	36·79	36·50				
					Wheat, 1940.						
P_0	45·88	42·13	43·74	44·49	41·92	45·34	43·92	L_0	45·56	44·27	44·38
P_1	46·09	46·63	44·49	44·49	47·05	45·66	45·74	L_1	49·19	43·63	41·92
P_2	48·44	45·88	42·03	45·24	45·77	45·34	45·45	L_2	45·66	46·73	43·95
Mean	46·80	44·88	43·42	44·74	44·92	45·45	45·04				
					Wheat, 1937–40.						
P_0	40·28	40·22	39·60	40·09	39·55	40·45	40·03	L_0	42·62	42·25	41·67
P_1	42·51	43·81	44·35	43·15	43·87	43·65	43·56	L_1	42·86	42·53	41·54
P_2	43·55	43·80	42·56	43·29	43·51	43·11	43·30	L_2	40·86	43·05	43·30
Mean	42·11	42·61	42·17	42·18	42·31	42·40	42·30				
					Wheat (stubble-sown), 1939.						
P_0	29·73	35·93	37·96	35·29	31·76	36·57	34·54	L_0	33·47	39·78	45·77
P_1	35·72	41·71	48·76	42·56	40·96	42·67	42·06	L_1	31·23	38·29	43·53
P_2	32·73	40·53	49·83	41·17	40·32	41·60	41·03	L_2	33·47	40·10	47·27
Mean	32·73	39·39	45·52	39·67	37·68	40·28	39·21				
					Wheat (stubble-sown), 1940.						
P_0	21·39	21·92	23·85	21·82	22·03	23·31	22·39	L_0	22·99	25·56	28·87
P_1	24·17	28·45	30·05	28·45	26·41	27·81	27·56	L_1	21·92	25·67	26·73
P_2	23·63	28·45	30·26	27·16	25·88	29·30	27·45	L_2	24·28	27·59	28·55
Mean	23·06	26·27	28·05	25·81	24·77	26·81	25·80				

	Mean of all lime.			Mean of all nitrogen.				Mean of all phosphate.			
	N_0	N_1	N_2	L_0	L_1	L_2	Mean		N_0	N_1	N_2
Wheat (stubble-sown), 1937–40.											
P_0	29·58	33·88	35·89	33·32	32·79	33·24	**33·12**	L_0	33·03	36·32	40·31
P_1	33·10	39·15	42·23	38·49	37·82	38·17	**38·16**	L_1	31·99	36·55	39·60
P_2	34·29	37·79	42·89	37·85	37·54	39·57	**38·32**	L_2	31·95	37·94	41·10
Mean	**32·32**	**36·94**	**40·34**	**36·55**	**36·05**	**36·99**	**36·53**				

Yields of temporary pasture (oven-dry) in cwt. per ac.

	N_0	N_1	N_2	P_0	P_1	P_2	L_0	L_1	L_2
Rotation A.									
1939	41·65	42·43	41·54	38·57	42·54	44·51	39·96	41·45	44·22
1940	20·04	21·91	22·97	18·13	22·47	24·31	20·90	20·61	23·41
Mean 1938–40	**30·06**	**31·53**	**31·69**	**28·63**	**31·75**	**32·90**	**30·24**	**30·70**	**32·34**
Rotation B.									
1939	30·88	30·55	31·19	28·54	30·64	33·44	29·91	30·61	32·10
1940	15·72	15·70	14·38	15·62	15·31	14·85	16·14	15·32	14·34
Mean 1938–40	**22·22**	**21·38**	**22·11**	**20·67**	**21·79**	**23·25**	**21·77**	**21·93**	**22·01**
Rotation C.									
1939	32·38	33·57	32·67	27·64	33·24	37·73	32·91	30·87	34·83
1940	17·60	16·03	19·60	15·01	17·58	20·64	16·39	17·97	18·87
Mean 1938–40	**23·35**	**23·56**	**24·65**	**20·45**	**23·87**	**27·24**	**23·05**	**23·13**	**25·38**
Rotation D.									
1939	35·89	34·07	37·63	34·29	34·92	38·37	33·00	37·66	36·92
1940	15·91	17·34	16·22	14·68	17·26	17·54	15·74	16·83	16·91
Mean 1938–40	**24·69**	**24·31**	**25·17**	**23·43**	**24·30**	**26·44**	**23·45**	**25·26**	**25·45**

No statistical analyses have yet been carried out on the data from this experiment.

Census analyses (Means 1938–40).

Wheat on fallow.

	N_0	N_1	N_2	P_0	P_1	P_2	L_0	L_1	L_2
Seeding:									
Grain sown per ft.	10·5	10·5	10·5	10·5	10·5	10·5	10·5	10·5	10·5
Germination:									
Plants per ft. at brairding	7·1	7·2	7·3	7·3	7·1	7·2	7·1	7·1	7·3
Tillering:									
Tillers per ft. at max. tillering	25·6	29·0	35·3	22·0	32·7	34·6	30·0	31·4	28·4
Harvest:									
Ears per ft.	13·5	14·4	15·2	11·0	15·2	16·8	13·9	15·1	14·1
Grains per ear	36·8	37·2	37·2	37·6	37·2	36·5	37·5	36·8	36·7
Av. wt. of 1,000 grains (grm.)	48·7	47·5	47·8	49·3	47·7	46·9	48·4	47·6	47·8
Yield (bush. per ac.)	36·73	36·11	37·33	32·72	38·49	38·96	36·28	36·76	37·13

Barley on stubble.

	N_0	N_1	N_2	P_0	P_1	P_2	L_0	L_1	L_2
Seeding:									
Grains sown per ft.	11·2	11·2	11·2	11·2	11·2	11·2	11·2	11·2	11·2
Germination:									
Plants per ft. at brairding	8·1	8·2	8·5	8·3	8·3	8·2	8·2	8·4	8·3
Tillering:									
Tillers per ft. at max. tillering	31·3	37·2	45·5	32·0	40·9	40·8	36·1	38·3	39·5
Harvest:									
Ears per ft.	16·9	19·8	22·8	17·7	21·3	20·5	19·3	20·0	20·3
Grains per ear	23·5	23·8	24·3	23·8	24·2	23·7	23·8	24·0	24·0
Av. wt. of 1,000 grains (grm.)	45·2	44·0	41·1	44·4	42·6	43·6	43·6	43·6	43·1
Yield (bush. per ac.)	42·00	49·75	52·03	45·04	49·58	49·15	47·55	48·06	48·17

4. EFFECT OF TIME OF SOWING, SEED RATE, AND SUPERPHOSPHATE ON THE YIELD OF FLAX, 1939.

Variety: Liral Crown.

Seed rate: 20, 40, 60, and 80 lb. per acre.

Superphosphate: P_1 = 1 cwt. per ac.; P_2 = 2 cwt. per ac.

Time of sowing: E = sown early, 23rd May. L = sown late, 3rd July.

Treatments: All combinations of time of sowing, seed rate, and superphosphate.

Design: 4 randomized blocks of early and late sowings. All combinations of seed rate and superphosphate randomized within each main plot. Total plots, 64.

Area of main plot = $\frac{8}{56}$th acre; area of sub-plot = $\frac{1}{56}$th acre.

Mean yields of seed in bushels per ac. Mean of all phosphate ± 0·358.

	Seed rate: lb. per ac.				Mean.	Difference.
Time of sowing.	20	40	60	80	± 0·418	± 0·591
E	9·30	13·38	12·84	13·28	**12·20**	—
L	3·19	5·41	6·19	6·47	**5·31**	*— 6·89*
Mean ± 0·253	**6·25**	**9·39**	**9·52**	**9·87**	**8·76**	—
Difference ± 0·358	—	*+ 3·14*	*+ 0·13*	*+ 0·35*	—	—

Mean yields of seed and total produce. Mean of all seed rates ± 1·165.

	Seed (bush. per ac.) ± 0·253.					Total produce (cwt. per ac.).			
			Mean.	Diff.				Mean.	Diff.
Phosphate	E	L	± 0·179	± 0·253		E	L	± 0·824	± 1·165
P_1	12·42	4·84	**8·63**	—		50·83	22·85	**36·84**	—
P_2	11·99	5·79	**8·89**	*+ 0·26*		50·37	26·46	**38·41**	*+ 1·57*
					Mean.				
Mean ± 0·418	**12·20**	**5·31**	**8·76**	—	± 1·749	**50·60**	**24·66**	**37·63**	—
					Diff.				
Diff. ± 0·591	—	*— 6·89*	—	—	± 2·473	—	*— 25·94*	—	—

Significant effects due to time of sowing, seed rate, and interaction of sowing date and phosphate.

Mean yields of total produce in cwt. per ac. Mean of all phosphate ± 1·648.

	Seed rate: lb. per ac.				Mean.	Difference.
Time of sowing.	20	40	60	80	± 1·749	± 2·473
E	31·83	52·61	56·98	60·98	**50·60**	—
L	14·69	24·19	28·53	31·23	**24·66**	*— 25·94*
Mean ± 1·165	**23·26**	**38·40**	**42·76**	**46·11**	**37·63**	—
Difference ± 1·648	—	*+ 15·14*	*+ 4·36*	*+ 3·35*	—	—

S.D. of difference between two means of 8 sub-plots = 2·330.

Significant effects due to time of sowing, seed rate, and their interaction.

5. EFFECT OF TIME OF SOWING AND SEED RATE ON THE YIELD OF FLAX, 1940.

Variety: Liral Crown.

Seed rate: 40, 60, and 80 lb. per acre.

Superphosphate: Basal dressing of 1½ cwt. per acre.

Time of sowing: 8th May, 22nd May, 5th June.

Treatments: All combinations of time of sowing and seed rate.

Design: 4 randomized blocks of 9 plots each, with 3 times of sowing in sub-blocks of 3 plots receiving differential seeding rates. Total plots, 36.

Area of main plot (sub-block) = $\frac{3}{57}$th acre; area of unit plot = $\frac{1}{57}$th acre.

Mean yields of seed in bushels per ac. ± 0·593.

Seed rate: lb. per ac.	Time of sowing. 8th May.	22nd May.	5th June.	Mean of times of sowing. ± 0·342	Difference. ± 0·484
40	10·43	7·63	7·03	**8·36**	—
60	10·02	6·70	6·69	**7·80**	*— 0·56*
80	9·08	6·89	6·74	**7·57**	*— 0·23*
Mean of all seed rates ± 0·174	**9·84**	**7·07**	**6·82**	**7·91**	—
Difference ± 0·246	—	*— 2·77*	*— 0·25*	—	—

Significant increases with earliness of sowing.

Mean yields of total produce in cwt. per ac. ± 1·120.

Seed rate: lb. per ac.	Time of sowing. 8th May.	22nd May.	5th June	Mean of times of sowing. ± 0·646	Difference. ± 0·914
40	52·00	40·99	37·22	**43·40**	—
60	55·92	46·25	40·06	**47·41**	*+ 4·01*
80	60·54	49·84	40·29	**50·22**	*+ 2·81*
Mean of all seed rates ± 0·530	**56·15**	**45·69**	**39·19**	**47·01**	—
Difference ± 0·749	—	*— 10·46*	*— 6·50*	—	—

Significant increases with increased seed rate and earliness of sowing.
Interaction insignificant.

6. EFFECT OF TIME OF SOWING AND SEED RATE ON THE YIELD OF FLAX, 1937–40.

Variety: Liral Crown.

Treatments: The treatments have varied in some respects from season to season, and are described in this (Tables 4 and 5) and the previous report (1937–38). The yields from treatments common to all four seasons are summarized in the tables presented below.

Basal dressing of superphosphate: 2 cwt. per acre, 1937–39; 1½ cwt. per acre, 1940.

Mean yields of seed in bushels per ac.

Year	Early sown. Seed rate: lb. per ac. 40	60	80	Mean	Late sown. Seed rate: lb. per ac. 40	60	80	Mean
1937	13·58	11·99	8·75	**11·77**	7·81	7·87	7·50	**7·66**
1938	8·79	8·72	7·64	**8·38**	6·18	6·23	7·08	**6·50**
1939	13·63	12·17	13·06	**12·95**	6·16	6·62	6·94	**6·57**
1940	10·43	10·02	9·08	**9·84**	7·03	6·69	6·74	**6·82**
Mean	**11·61**	**10·72**	**9·88**	**10·74**	**6·80**	**6·80**	**7·06**	**6·89**

Mean yields of total produce in cwt. per ac.

1937	48·31	49·75	52·12	**50·06**	36·59	36·72	40·28	**37·86**
1938	47·69	50·54	51·16	**49·80**	30·49	31·42	36·72	**32·88**
1939	52·78	57·04	60·37	**56·73**	26·87	31·00	32·87	**30·25**
1940	52·00	55·92	60·54	**56·15**	37·22	40·06	40·29	**39·19**
Mean	**50·20**	**53·31**	**56·05**	**53·18**	**32·79**	**34·80**	**37·54**	**35·04**

Increase due to early sowing: seed, 3·85 bushels per ac.; total produce, 18·14 cwt. per ac.

Percentage of fibre recovered after retting and scutching.

(Early seedings 1938, 1939).

Year.	Seed rate: lb. per ac. 20	40	60	80	Mean.
1938	11·7	14·1	15·1	15·5	**14·1**
1939	15·9	16·7	18·4	19·1	**17·6**
Mean	**13·8**	**15·4**	**16·8**	**17·3**	**15·8**

The treatments common to all four seasons and listed in the above table are being continued.

7. VARIETY TRIAL WITH LINSEED, 1940.

Variety of crop: Ten varieties as tabulated.
Time of sowing: 22nd May, 1940, on fallow.
Fertilizer: 1½ cwt. superphosphate per ac.
Design: 4 replications in randomized blocks.
Size of unit plot = 1/92nd acre.

Variety.	Yield of seed bush. per ac.	No. of seeds per gm.	Oil content. %	Iodine value (WIJS) of extracted oil.	Acid value of extracted Oil.
Punjab	15·75	168	37·75	182·8	1·1
Abyssinian	13·64	251	39·24	193·5	1·6
Argentine	9·65	155	39·29	189·0	1·9
Newland	8·81	208	38·83	195·3	2·1
Redwing	8·70	203	38·07	192·5	1·6
Bison	8·12	183	37·59	187·8	2·2
Victorian	8·10	219	38·26	182·5	2·6
U.S.A. Hybrid	7·91	213	36·72	189·0	2·0
New Zealand	7·35	226	38·15	194·9	2·0
Ottawa	6·66	196	38·66	193·8	1·7

8. INFLUENCE OF TOP-DRESSING ON THE YIELD OF NATURAL PASTURE.

Investigation commenced in 1925 on unimproved natural grassland dominated by *Danthonia* spp.

Manurial treatments:

A. Superphosphate 185 lb. (40 lb. P_2O_5) per ac.
B. Superphosphate 185 lb. + nitrate of soda 78 lb. (12½ lb. N) per ac.
C. Nil.
D. Ground rock phosphate 103 lb. (40 lb. P_2O_5) per ac.
E. Basic slag 260 lb. (40 lb. P_2O_5) per ac.

The above dressings have been applied annually since 1925.

Plots are grazed individually by sheep, and estimates of the yields are obtained from 8 protected quadrats, 2½ sq. metres in area, on each plot.

Design: Single replication of each treatment.

Area of plot = 10 sq. chains (10 × 1).

Regression analysis of the relationship between yield and monthly, tri-monthly, and annual rainfall carried out at conclusion of ten seasons.

Grazing management redesigned in 1940 to accommodate separate flocks of Merino sheep on each of the above five plots and on three additional plots: (F) natural pasture, mainly of annuals, receiving 20 lb. P_2O_5 per acre, (G) seeded pasture; (H) seeded pasture, with portion cut for hay and fed back. Plots subdivided into five equal sub-plots of 1/5·8th acre, and grazed on a 5-weekly rotation, one week per sub-plot. Sheep weighed monthly; wool weighed and classed separately for each sheep.

Total yield in cwt. air-dry herbage per ac.

Year.	Treatment. A	B	C	D	E	Mean.
1925	27·74	30·69	21·76	18·57	25·49	24·85
1926	43·20	43·57	28·35	27·16	49·15	38·29
1927	28·54	27·95	18·00	15·95	24·84	23·06
1928	39·63	41·81	24·31	27·89	35·58	33·84
1929	33·70	37·45	17·69	25·63	35·31	29·96
1930	30·32	39·86	20·67	30·56	43·56	32·99
1931	47·50	63·12	41·43	52·60	58·06	52·54
1932	75·66	81·11	56·92	70·34	78·25	72·46
1933	64·70	63·58	51·43	61·72	57·61	59·81
1934	38·00	52·44	20·23	43·66	48·67	40·60
1935	72·90	70·90	41·49	58·25	62·72	61·25
1936	42·24	48·67	29·54	47·30	41·15	41·78
1937	51·69	59·09	36·21	59·48	61·07	53·51
1938	54·47	57·62	34·92	60·11	64·06	54·24
1939	50·57	66·37	48·97	63·36	62·40	58·33
1940	26·48	30·30	29·48	33·86	28·41	29·71
Mean	45·46	50·91	32·59	43·53	48·52	44·20

Yield of legumes in the pasture. Cwt. air-dry herbage per ac.

Year.	Treatment. A	B	C	D	E	Mean.
1925	20·25	18·35	6·57	5·64	14·35	13·03
1926	20·17	16·66	9·49	9·18	19·12	14·92
1927	4·29	0·40	1·02	0·44	2·43	1·71
1928	23·00	13·78	0·90	3·81	4·28	9·15
1929	14·45	8·24	2·18	4·74	13·30	8·58
1930	1·71	0·54	0·39	1·57	1·63	1·15
1931	6·80	2·79	3·56	5·33	5·18	4·73
1932	9·35	7·33	9·94	18·01	12·58	11·44
1933	5·40	2·23	4·20	4·24	3·10	3·83
1934	1·89	1·17	2·34	1·95	0·06	1·48
1935	44·53	27·97	10·14	20·69	18·63	24·39
1936	7·84	14·89	8·82	15·08	9·95	11·32
1937	19·30	15·15	9·69	14·63	31·34	18·02
1938	14·31	4·40	6·83	17·50	15·85	11·78
1939	6·85	4·13	12·73	17·73	11·26	10·54
1940	5·48	4·43	3·16	1·83	3·37	3·65
Mean	12·85	8·90	5·75	8·90	10·40	9·36

Stock-carrying capacity. Sheep days of grazing per ac.

Year.	Treatment. A	B	C	D	E	Mean.
1928	900	935	465	640	708	729
1929	877	859	509	603	817	733
1930	813	1,110	592	667	1,121	861
1931	1,271	1,551	902	1,072	1,355	1,230
1932	2,421	2,634	1,764	2,215	2,840	2,375
1933	2,724	3,211	1,868	2,625	3,175	2,721
1934	1,250	1,518	754	1,051	1,370	1,189
1935	1,953	2,341	1,431	2,083	2,257	2,013
1936	1,237	1,372	691	1,296	1,166	1,152
1937	1,618	1,960	1,204	1,863	1,767	1,682
1938	2,659	2,768	1,466	2,494	2,591	2,396
1939	1,778	1,905	1,013	1,907	2,102	1,741
1940	1,181	1,129	1,006	1,190	1,085	1,118
Mean	1,591	1,792	1,051	1,516	1,720	1,534

9. EFFECT OF NITROGEN AS SULPHATE OF AMMONIA ON THE YIELD OF A SEEDED PERMANENT PASTURE UNDER DIFFERENT SYSTEMS OF MANAGEMENT.

Pasture mixture: Wimmera rye-grass, New Zealand certified perennial rye-grass, *Phalaris tuberosa*, and Dwalganup subterranean clover, sown 3rd June, 1930.

Manurial treatment: Basal dressing of 2 cwt. superphosphate per ac. = P.
Sulphate of ammonia, 2 cwt. per ac. = N.

Systems of management:

A. Mown 4 times per annum, and the herbage removed.
B. Mown as above, but the herbage returned to the plots for grazing by sheep.
C. Grazed by sheep without pre-cutting; sampled for yield from 1932 onwards.
D. Cut as hay at conclusion of seasonal growth.

Design: Sulphate of ammonia applied to strips 400 × 9 links on the ABBA system in quadruplicate.

Area subdivided into 4 blocks, to each of which is applied one of the above four systems of management.

Correlation coefficients between yield and monthly, tri-monthly, and annual rainfall determined at conclusion of ten seasons.

Yield of herbage in cwt. per ac.

	System of management.							
	A		B		C		D	
Year.	P	PN	P	PN	P	PN	P	PN
1930	40·95	44·20	28·09	32·02	*	*	30·44	37·32
1931	20·90	31·64	32·41	42·64	*	*	24·96	45·58
1932	38·13	34·89	41·80	45·66	50·55	60·34	63·74	62·36
1933	38·36	32·39	25·13	21·88	28·57	25·65	65·55	61·81
1934	51·86	49·03	58·93	62·32	88·33	76·52	48·44	45·80
1935	57·97	50·88	51·15	49·35	63·71	67·03	67·39	62·92
1936	47·41	43·79	42·24	43·10	58·68	62·37	39·96	38·39
1937	46·53	45·62	48·48	52·04	55·52	57·70	55·63	54·14
1938	41·62	35·85	37·80	37·00	62·69	68·35	59·81	57·23
1939	53·62	48·74	53·73	70·45	79·21	84·71	65·10	64·16
1940	38·99	32·66	21·87	19·75	42·13	44·96	43·44	45·37
Mean	**43·30**	**40·97**	**40·15**	**43·29**	**58·82**	**60·85**	**51·31**	**52·28**

* Records not taken.

Mean yields of the principal botanical constitutents in cwt. per ac., 1933–40.

System of management	*Lolium.*		*Phalaris.*		*Trifolium.*		Total sown species.	
	P	PN	P	PN	P	PN	P	PN
A	6·51	9·65	18·75	16·49	19·31	12·53	44·87	38·67
B	11·29	14·20	21·81	21·98	4·53	1·39	37·63	37·57
C	7·73	9·64	39·78	40·16	3·26	0·86	50·77	50·66
D	2·21	3·25	42·56	39·31	0·50	0·18	45·27	42·73

10. EFFECT OF SUPERPHOSPHATE AND SURFACE CULTIVATION ON THE YIELD AND BOTANICAL COMPOSITION OF A SEEDED PASTURE.

Pasture mixture: *Phalaris tuberosa*, Wimmera rye-grass, Dwalganup subterranean clover, sown 15th May, 1936.

Superphosphate: Dressing applied per acre per annum, P_0 = nil, P_1 = 1 cwt., P_2 = 2 cwt., P_3 = 3 cwt.

Cultivation: C_0 = nil, C_1 = surface cultivated annually each autumn.

Design: Phosphate treatments arranged in a 4 × 4 Latin square.

Area of main plot = $\frac{1}{12·5}$ acre. Half of each main plot surface cultivated. Plots sampled for yield, and grazed 4 times annually at 6-weekly intervals.

Yield of oven-dry herbage in cwt. per ac.

1939	P_0	P_1	P_2	P_3	Mean ± 1·00
C_0	43·32	54·57	56·89	55·88	**52·67**
C_1	46·03	50·62	56·42	59·17	**53·06**
Mean ± 1·62	**44·67**	**52·60**	**56·66**	**57·53**	**52·87**
1940					Mean ±0·59
C_0	25·67	31·72	29·12	29·79	**29·07**
C_1	24·54	28·09	29·06	31·54	**28·31**
Mean ± 0·78	**25·11**	**29·90**	**29·09**	**30·65**	**28·69**
Mean 1937–40					
C_0	30·32	39·84	39·23	39·28	**37·17**
C_1	32·13	35·96	39·61	42·08	**37·45**
Mean	**31·22**	**37·90**	**39·42**	**40·68**	**37·31**

11. EFFECT OF DIFFERENTIAL GRAZING MANAGEMENT ON THE YIELD AND BOTANICAL COMPOSITION OF A SEEDED PASTURE.

Pasture mixture: *Phalaris tuberosa*, Wimmera rye-grass, and Dwalganup subterranean clover, sown, 15th May, 1936.

Basal fertilizer treatment: Superphosphate, 2 cwt. per acre per annum.

Intensities of grazing: 2, 4, and 6 sheep per acre per annum.

Grazing cycles: 3, 6, and 9 weeks.

Mowing treatment: Hay and no hay.

Treatments: All combinations of intensity of grazing, grazing cycle, and hay treatment.

Design: 18 treatments in 3 randomized blocks.

Area of plot = 1/7th acre. Each plot is separately fenced. Each plot is individually grazed by Merino wethers for 6 days in each cycle.

Annual yield of oven-dry herbage in cwt. per ac., 1939 (no hay plots only).

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks). 3	6	9	Mean.
2	34·63	24·68	37·88	**32·40**
4	36·72	37·55	39·91	**38·06**
6	46·41	39·62	43·58	**43·20**
Mean	**39·25**	**33·95**	**40·46**	**37·89**

Yield of oven-dry herbage in cwt. per ac. to September, 1940.

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks). 3	6	9	Mean.
2	31·54	22·99	22·13	**25·55**
4	22·19	27·17	22·37	**23·91**
6	26·87	24·25	24·95	**25·35**
Mean	**26·86**	**24·80**	**23·15**	**24·94**

Mean hay yields in cwt. per ac., 1939–40.

Intensity of grazing sheep per ac. per annum.	Grazing cycle (weeks). 3	6	9	Mean.
2	31·5	30·9	30·6	**31·0**
4	29·7	26·9	22·2	**26·3**
6	23·0	21·3	18·3	**20·9**
Mean	**28·1**	**26·4**	**23·7**	**26·1**

Percentage botanical composition (120 weeks after commencement of experiment).

	Intensity of grazing sheep per ac. per annum.	Wimmera rye-grass.	*Phalaris.*	Sub. clover.	Misc. (weeds).	Total.
No hay	2	1·6	72·9	21·4	4·1	100·0
	4	2·1	53·9	28·5	15·5	100·0
	6	1·1	43·5	30·8	24·6	100·0
Hay	2	0·1	50·6	37·0	12·3	100·0
	4	0·4	32·9	34·9	31·8	100·0
	6	0·1	38·1	32·2	29·6	100·0
	Grazing cycle (weeks)					
No hay	3	0·7	49·4	30·9	19·0	100·0
	6	0·7	57·2	26·5	15·6	100·0
	9	3·6	65·0	22·8	8·6	100·0
Hay	3	0·2	33·1	49·1	17·6	100·0
	6	0·1	42·5	32·4	25·0	100·0
	9	0·3	46·8	24·9	28·0	100·0

12. GRAZING VALUE OF TOP-DRESSED NATURAL AND SEEDED PASTURES AT KYBYBOLITE.

Four areas each of natural pasture, Wimmera rye-grass + subterranean clover, and *Phalaris tuberosa* + subterranean clover, aggregating 17·00, 17·93, and 17·75 acres respectively.

Manurial treatment: 2 cwt. superphosphate per ac. applied annually in the autumn.

System of management: Grazed rotationally by sheep. Three flocks, each of 40 comeback ewe weaners were allocated to each pasture type.

Live weights of sheep recorded monthly: Yields of pasture from enclosed quadrat areas taken once each season: estimations of percentage ground-cover of all pasture species carried out during the growing season: wool and lambing data recorded.

Commencement of grazing, 14/4/35. Grazing terminated, 19/4/40.

Live weight increases of each flock in lb. per ac.

	Natural pasture.	Wimmera rye + sub. clover.	*Phalaris* + sub. clover.
Live weight gain (lb.)	86·1	94·7	112·3

Weight of lambs produced (1938 and 1939) in lb. per ac.

Flock.	1938.	1939.	Total.
Natural pasture	131·3	149·4	280·7
Wimmera rye-grass + sub. clover	183·6	152·6	336·2
Phalaris + sub. clover	177·2	128·1	305·3

Mean weight and value of wool per sheep.

Flock.	1935. lb.	oz.	value s. d.	1936. lb.	oz.	value s. d.	1937. lb.	oz.	value s. d.	1938. lb.	oz.	value s. d.	1939. lb.	oz.	value s. d.	Mean. lb.	oz.	value s. d.
Natural pasture	8	6	10/3	6	9	9/7	11	7	17/6	10	5	10/10	10	5	12/3	9	6	12/1
Wimmera rye-grass + sub. clover	9	3	10/9	6	14	10/2	12	12	19/7	10	7	10/9	10	2	11/10	9	14	12/7
Phalaris + sub. clover	8	0	9/8	7	6	11/1	12	8	19/11	10	13	11/1	10	11	12/3	9	14	12/11

Mean yields of oven-dry herbage in cwt. per ac.

Flock.	1935.	1936.	1937.	1938.	1939.	Mean.
Natural pasture	58·24	52·13	48·41	44·90	47·71	**50·28**
Wimmera rye-grass + sub. clover	62·94	71·89	56·58	64·54	78·15	**66·82**
Phalaris + sub. clover	62·26	59·22	57·30	52·03	66·53	**59·47**

Mean number of sheep carried per ac. per annum.

Flock.	1935–6.	1936–7.	1937–8.	1938–9.	1939–40.	Mean.
Natural pasture	4·05	3·03	3·12	2·67	3·03	**3·18**
Wimmera rye-grass + sub. clover	4·42	3·04	3·57	3·43	4·36	**3·76**
Phalaris + sub. clover	4·69	3·10	3·70	3·46	4·52	**3·89**

Percentage lambing from ewes of each flock.

Flock.	1936.	1937.	1938.	1939.	Mean.
Natural pasture	65·8	86·5	100·0	102·9	**88·8**
Wimmera rye-grass + sub. clover	85·0	100·0	112·8	107·7	**101·4**
Phalaris + sub. clover	82·5	85·0	117·9	105·1	**97·6**

13. ESTABLISHMENT AND YIELD OF CEREAL CROPS AND HERBAGE PLANTS ON A SAND DRIFT AT PALLAMANA.

(a) Initial Seedings under Conditions of Severe Drift, 1937.

Triplicated plots of rye corn, barley, and Wimmera rye-grass were seeded in single widths of a 20-hoe drill, 5 chains in length. Across these were sown in strips, lucerne, Dwalganup subterranean clover, cluster, burr, and barrel clovers, peas, and evening primrose.

Percentage establishment, 12 weeks after seeding.

	Rye corn.	Barley.	Wimmera rye-grass.	Peas.	Lucerne.	Sub. clover.	Barrel medic.	Evening primrose.
Percentage establishment	45·2	38·8	4·4	11·1	1·1	13·8	1·1	0·1

Yield of total dry matter and grain in lb. per ac., 1937.

	Rye corn.	Barley.	All other species.
Total dry matter	434·4	20·9	nil
Grain	192·5	0·6	nil

(b) Seedings of Herbage Species in Rye Stubble, 1938.

Replicated plots were sown to the following species, alone and in various combinations: Lucerne, barrel medic, Dwalganup subterranean clover, perennial veldt grass, Wimmera rye-grass, evening primrose, and Mediterranean grass.

Percentage establishment, and survival of perennial species.

	Lucerne.	Barrel medic.	Sub. clover.	Perveldt grass.	Wimmera rye-grass.	Evening primrose.	Mediterranean grass.
Percentage establishment	38·0	41·9	39·1	39·9	49·6	7·4	2·5
Percentage survival after first summer	1·4			0·6			

Mean yields of sown species in lb. oven-dry herbage per ac., 1938–40.

Year.	Lucerne.	Barrel medic.	Sub. clover.	Per veldt grass.	Wimmera rye-grass.	Evening primrose.	Mediterranean grass.	Mean.
1938	46·7	274·3	13·2	nil	2·2	12·3	nil	49·8
1939	26·9	2,781·0	60·5	1·1	3·4	247·5	29·1	449·9
1940	17·6	21·1	0·9	0·3	1·8	628·3	3·5	96·2
Mean	**30·4**	**1,025·5**	**24·9**	**0·5**	**2·5**	**296·0**	**10·9**	**198·6**